

The Victorian Naturalist

Volume 139 (4)

August 2022



Published by The Field Naturalists Club of Victoria since 1884

From the editors

The style of this journal is based largely on that set out in the Australian Government Style Manual, which is now available only online at <<https://www.stylemanual.gov.au>>. A number of amendments have been made recently to this version, which necessitate corresponding changes in the style applied in *The Victorian Naturalist*. Readers and contributors are alerted to the following changes:

- **Numbers**—numbers used within a sentence, with the exception of zero and one, should, in most cases, be rendered as numerals. Previously, this was the case only with greater than 9. Exceptions are listed under 'Choosing numbers or words'. If the sentence begins with a number, it must be spelled out, e.g. 'Eight days a week ...'
- **Abbreviated Latin terms**
 - Do not use italics: e.g. not *e.g.*; i.e. not *i.e.*; et al. not *et al.*
 - Do not follow e.g. or i.e. with a comma.

The Victorian Naturalist
is published six times per year by the

Field Naturalists Club of Victoria Inc

Registered Office: FNCV, 1 Gardenia Street, Blackburn, Victoria 3130, Australia.

Postal Address: FNCV, PO Box 13, Blackburn, Victoria 3130, Australia.

Phone +61 (03) 9877 9860; email: admin@fncv.org.au

www.fncv.org.au

Patron: The Governor of Victoria, the Honorable Linda Dessau AC

Address correspondence to:

The Editors, *The Victorian Naturalist*, PO Box 13, Blackburn, Victoria 3130, Australia.

Phone: (03) 9877 9860. Email: vicnat@fncv.org.au

The opinions expressed in papers and book reviews published in *The Victorian Naturalist* are those of the authors and do not necessarily represent the views of the FNCV. Copyright of all original material published in *The Victorian Naturalist* remains with the author.

Yearly Subscription Rates – The Field Naturalists Club of Victoria Inc

(effective from 1 July 2022)

Membership category

Single	\$ 88	Institutional	
Family	\$114	- within Australia	\$176
Single Country/Concession	\$ 66	- overseas	AUD189
Family Country/Concession	\$ 88		
*Junior Family	\$ 53		
Junior additional	\$ 18	Schools/Clubs	\$101
Student	\$ 40		

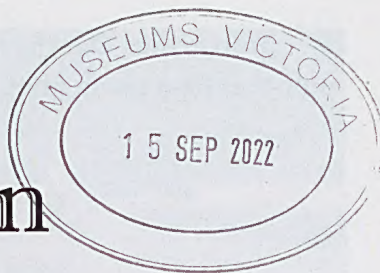
* Junior membership is entitled to receive *Junior Naturalist* only.

Non-member fees: Meetings \$3; Excursions \$5

All subscription enquiries should be sent to:
FNCV, PO Box 13, Blackburn, Victoria 3130, Australia

Phone 61 3 9877 9860. Email: admin@fncv.org.au

The Victorian Naturalist



Volume 139 (4) 2022

August



Editors: Gary Presland, Maria Gibson, Sue Forster

Editorial Assistant: Virgil Hubregtse

From the editors	94
Research Report	
March flies <i>Dasybasis froggatti</i> and <i>Copidapha maculiventris</i> : a population crash after reduced plant flowering in the alpine zone of Kosciuszko National Park, by Ken Green and Mary G Green.....	96
Contributions	
The case of a Pygmy Hippopotamus <i>Choeropsis liberiensis</i> in the Northern Territory, Australia: extrapolating from a Colombian experience, by Matthew Mo.....	103
Diet of the Yellow-footed Antechinus <i>Antechinus flavipes</i> , by Alan York, Amanda Ashton and Julian Di Stefano.....	112
Naturalist Note	
Australasian Grebe <i>Tachybaptus novaehollandiae</i> activity, including some unusual breeding behaviour, on 2 waterbodies in Clayton, Victoria, by Virgil Hubregtse.....	117

ISSN 0042-5184

Front cover: Australasian Grebe *Tachybaptus novaehollandiae* on nest platform at the flood-retarding basin, Monash University, Clayton Campus. Photo Jurrie Hubregtse.

Museum Victoria



71400

March flies *Dasybasis froggatti* and *Copidapha maculiventris*: a population crash after reduced plant flowering in the alpine zone of Kosciuszko National Park

Ken Green^{1*} and Mary G Green

¹Australian National University,
College of Asia and the Pacific, Canberra, ACT 2601.
*Corresponding author: <kenpetergreen@gmail.com>.

Abstract

There are 2 common species of March fly (family Tabanidae in the order Diptera) in the Snowy Mountains. In the summer of 2019/2020, adult populations of *Dasybasis froggatti*, the more alpine of the 2 species, disappeared almost completely in the alpine zone whereas *Copidapha maculiventris* was not affected. We studied these species in Kosciuszko National Park with minimal human interactions, and the crash occurred before the fire season. Diptera are the most important pollinators of alpine plants in the Snowy Mountains. March flies typically appear on or about 10 December and depend on plant nectar for their food. Before the end of December, 50 to 80 species of plant normally flower, and 3 of these are important to *D. froggatti*. In the hot period leading to the summer fires of 2019/2020, only 36 species flowered, compared to an average of 64, with only one plant being seen for many species. Unlike *D. froggatti*, *C. maculiventris* can feed from flowers of *Eucalyptus* at the treeline. At the treeline, our records indicate that the warmest final 15 days of the year previously had an average temperature of 8.28°C, whereas in 2019 the average was 10.92°C. The high temperatures probably caused the lack of flowering, resulting in the decline in March fly populations. In 2021 average temperature for the warmest final 15 days of the year was 9.41°C and the average number of March flies were again present. (*The Victorian Naturalist* 139 (4), 2022, 96–103)

Keywords: effects of snowmelt, food resource availability, effects of temperature

Introduction

There has been concern in recent years over the general decline in insect numbers. Causes such as changes to farmland use, general agricultural practices and increased pesticide use have been described for Bogong Moth decline (Green et al. 2021). However, the effects of these practices occur outside the Snowy Mountains and are observed only when the Bogong Moths arrive (or fail to arrive) in the mountains, as the use of pesticides in Kosciuszko National Park (KNP) is strictly limited. However, climate change is a threat to insects regardless of land use. This has been known for a long time (Green and Osborne 2012). The March flies *Dasybasis froggatti* and *Copidapha* (previously *Scaptia*) *maculiventris* (Tabanidae) are well known by walkers above the snowline; however, in the summer of 2019/2020, they were notable for their absence. Although March flies typically appear on or about 10 December, in 2019 none had emerged by 13 December (personal records—the authors have been recording the numbers of March flies opportunistically since 2006). Subsequently, 3 KNP staff reported ‘very few’

March flies (John White pers. comm. December 2019) during the daily walk along the Main Range Track by a ranger. On 30 December 2019, the authors saw none. On 31 December 2019, while assisting the evacuation of walkers from the Main Range Track, due to threatening fires, the walkers told the authors they were surprised they had not seen March flies, as they normally had over the many years of doing the walk. The Park was then closed to the public for about 3 weeks. The fire events of the 2019/2020 summer had a major impact on south-eastern Australia and burnt a third of KNP. Although the alpine zone was not burnt, the authors’ search for March flies was not resumed until the Park reopened on 24 January 2020. At this time, March flies were still reported as uncommon by Park staff (John White, pers. comm. January 2020) and the authors recorded only one species, the large, green-eyed *C. maculiventris* (Fig. 1).

March flies are common in all snow-country areas. *Copidapha maculiventris* (Fig. 1) is the larger March fly, commonly seen near the



Fig. 1. The March fly *Copidapha maculiventris* has bright green eyes and is a larger species than *Dasybasis froggti*.



Fig. 2. The alpine March fly *Dasybasis froggti*, which is generally black and smaller than *Copidapha maculiventris*. Photo Liz O'Donnell.

lower Snowy River to Island Bend at 1200 m ASL, and *D. froggti* (Fig. 2) is the more alpine of the 2 species. Little is known regarding the lifecycle of Australian tabanids, although it is hypothesised that it could take between one and 4 years to complete development (Mackerras 1956, 1960). *Dasybasis froggti* is believed to have an annual life cycle (Fuller 1937; Green and Osborne 2012). The predacious larvae live in moist soil down to about 5 cm or deeper, and reach full growth by the autumn, wintering as dormant larvae before coming to the surface just before pupating (Fuller 1937; Green and Osborne 2012).

March flies are important pollinators in the high mountains, with *D. froggti* known to feed on nectar of 3 species, namely Snow Heath *Epacris petrophila*, Carpet Heath *Pentachondra pumila* and Alpine Baeckea *Baeckea gunniana* (Inouye and Pyke 1988). *Copidapha maculiventris* feeds on the nectar of a wide variety of native plants including *Eucalyptus* and *Grevillea* spp. (BD Lessard, pers. comm. 2020). The bites of March flies are inflicted only by the females, which need to feed on blood in order to develop their eggs; the males are purely nectar feeders. Thus, plant flowering could affect March fly numbers. Green (2006, 2010) published long-term studies of climate change impacts and found that the time of plant flowering was linked to date of snowmelt.

Very few publications present long-term records of regularly documented insect numbers. In this article, long-term data is presented

on summer March fly numbers in alpine and subalpine areas of KNP from 2006/2007 to 2021/2022. These data are examined in conjunction with plant flowering within the snow-free period to determine the possible cause(s) of a crash in March fly numbers.

Materials and methods

Over the period from 2006 to 2020, March flies of 2 species, *D. froggti* and *C. maculiventris*, in alpine and subalpine areas of KNP were identified and numbers counted. This was done opportunistically during lunch time in the field. The March flies commonly landed on 2 sites, Ken Green's (KG) gaiters and rucksack, both red to black in colour. The total number of each species seen per day was recorded. The number of days that March flies were counted per year varied owing to the opportunistic nature of the study.

To determine which dicotyledonous species flowered during the snow-free season, plant species in flower were recorded at regular intervals of 1 to 2 weeks from September to March or April, from the 2006/2007 flowering period to the present. The snow-free period in spring was recorded from the first date that Spencer's Creek snow course (which is regularly monitored by Snowy Hydro and observations published) was measured as being free of snow. The first date Snow Gum *Eucalyptus pauciflora* subsp. *niphophila* were seen to flower at the alpine treeline in the Snowy Mountains was recorded for 16 years during the period 1982 to the present.

Table 1. Average numbers of *Dasybasis froggatti* and *Copidapha maculiventris* recorded during lunch time breaks in alpine and subalpine areas of Kosciuszko National Park in the summers of 2006/2007 to 2021/2022 inclusive.

¹ March flies were not recorded on 11 December 2020 by 2 groups studying Bogong Moths. None were observed by walkers on 25 December 2020 on the 22 km Main Range Track, nor seen by National Parks staff from 21 December 2020 until January 2021. Our records commenced on 25 December 2020 with our first record for the season and continued through until 3 February 2021 with no records from 17 February except individual *Copidapha maculiventris* in alpine and subalpine areas.

² March flies were counted at lunchtime for 17 days from 10 January 2022 by NPWS staff, with an average of 14.9 individual *Dasybasis froggatti* (Dan Nichols, pers. comm. 2022).

Year	Alpine Average daily number of March flies			Subalpine Average daily number of March flies		
	<i>D. froggatti</i>	<i>C. maculiventris</i>	n	<i>D. froggatti</i>	<i>C. maculiventris</i>	n
2006/2007	6.6	1.6	(8)	0.0	10.0	(2)
2007/2008	11.2	0.2	(5)	0.1	5.3	(9)
2008/2009	2.3	0.3	(3)	0.0	6.0	(1)
2011/2012	10.0	0.3	(7)	-	-	-
2012/2013	21.0	0.0	(2)	0.0	9.7	(2)
2013/2014	8.0	0.5	(2)	0.0	21.0	(1)
2014/2015	-	-	-	0.0	7.0	(2)
2015/2016	18.5	0.8	(4)	-	-	(0)
2016/2017	7.3	1.1	(7)	1.0	6.0	(1)
2017/2018	5.0	1.0	(1)	-	-	-
2019/2020	0.6	1.0	(9)	1.0	3.0	(1)
2020/2021 ¹	1.9	0.4	(9)	-	-	-
2021/2022 ²	7.0	0.8	(4)	-	-	-
Total			61			19

Results

March flies above the treeline (i.e. in the alpine zone) consisted mainly of *D. froggatti*, while below the treeline (subalpine) they were mainly *C. maculiventris* (Table 1). The sample size per year varied from 2 to 9 counts.

The average population of *D. froggatti* from 2006/2007 to 2017/2018, over 39 days of sampling, ranged from an average of 2.3 to 21.0 flies and varied quite widely at times (Table 1). The maximum number of individuals in a single count for each of these years ranged from 4 to 35 flies. Of the 39 counts made, only one (the first record) was of zero flies. In the 9 counts made in 2019/2020, the maximum count was 2 flies (Table 1) while 5 of the 9 counts recorded zero flies, and this is what we describe as a population crash.

During the summer of 2019/2020, the 3-week closure of KNP meant that records of flowering plants could not be made. Hence data were recorded only until 30 December. Recording of flowering recommenced from 24 January 2020 and continued to 15 April 2020, when no new

flowers emerged. The flowering results in Table 2 are, therefore, first presented as the number of dicotyledons in flower from the end of the snow season until 30 December 2019, allowing for direct comparison between years. The number of species in flower during this period ranged from 32 to 80, with the least number of species occurring in 2019/2020—14 fewer species than reported in any other year. The second column in Table 2 shows the number of dicotyledons in flower over the entire snow-free period for each year, 72 to 97 species. Again, the least number of species in flower occurred in 2019/2020, and this was 10 fewer than occurred in any other year. The first snow-free period for the 13 years of sampling ranged from 5 October to 22 November, with that of 2019 occurring on 1 November (Table 2).

As it is known which plant species *D. froggatti* feed on, the date flowering was first observed for these species is presented (Table 2). The first observations of flowering in Snow Heath each year ranged from 12 November to 30 December, the latter being in the snow-free

Table 2. Flowering of dicotyledonous alpine plant species in Kosciuszko National Park from 2006 to 2021. During the summer of 2019/2020, flowering of plants was recorded until 30 December after which there was a 3-week closure of the Park because of wildfire. Recording of flowering plants recommenced on 24 January 2020 and continued until 15 April 2020.

¹Records for 2019/2020: 7 October 2019 = 1 species in flower; 10 October 2019 = 5 species; 13 December 2019 = 16 species; 30 December 2019 = 36 species; 24 January 2020 = 36 species; 1 January 2020 = 46 species.

Year	Number of Dicot species in flower		Date of first flowering			First snow-free date, Spencer's Creek snow course (Snowy Hydro)
	From the end of snow season to 31 December	Total for entire snow-season	Snow Heath	Carpet Heath	Alpine Baekea	
2006/2007	61	84	6 Dec		11 Jan	Oct 5
2007/2008	68	89	5 Dec		9 Jan	Oct 25
2008/2009	61	84	16 Dec		9 Jan	Oct 16
2009/2010	61	85	12 Nov	14 Dec	30 Dec	Nov 5
2010/2011	57	83	24 Dec	22 Jan	16 Jan	Oct 28
2011/2012	60	94	1 Dec	6 Jan	6 Jan	Oct 27
2012/2013	65	97	28 Nov	6 Jan	6 Jan	Nov 1
2013/2014	57	85	18 Nov	19 Feb	3 Jan	Oct 31
2014/2015	74	82	14 Nov	30 Dec	30 Dec	Oct 23
2015/2016	80	93	17 Nov	19 Nov	22 Dec	Oct 22
2016/2017	56	94	25 Nov	4 Jan	9 Jan	Nov 22
2019/2020 ¹	32	72	30 Dec	24 Jan	30 Dec	Nov 1
2020/2021	78	91	14 Nov	11 Dec	30 Dec	Oct 19

period of 2019/2020. The 5 records before that of 2019/2020 were all in November, as was that of 2020/2021. The first observation of flowering in Carpet Heath each year occurred over a longer period than for Snow Heath, ranging from 19 November to 19 February. The latest date for first flowering was recorded in 2013/2014 for Carpet Heath, although the record for 2019/2020 was comparatively late as well. In Alpine Baekea, the earliest first observed flowering each year occurred on 22 December and the latest on 16 January.

The first observed date of flowering of Snow Gums ranged from 30 November to 8 February. In 2022, flowering of Snow Gums was recorded from 6 January (Table 3) and lasted for 3 weeks.

Discussion

Because the March fly territories we studied are within KNP (area 6900 km²), there are few possible causes for a population crash. Insect sprays are not used in the park; herbicides are used mainly on roadsides, with only small areas of Orange Hawkweed *Hieracium aurantiacum* being sprayed in the alpine areas; and arsenic, transported into the Snowy Mountains by the migratory Bogong Moths *Agrotis infusa*, is

Table 3. First observed date of flowering of Snow Gums *Eucalyptus pauciflora* subsp. *niphophila* above the winter snowline in the Snowy Mountains.

Year	First summer flowering
1982	January 11
1986	January 3
1987	February 8
1995	January 6
1995	December 5
2001	January 8
2006	November 30
2007	December 5
2010	December 10
2012	January 12
2012	December 28
2015	November 30
2016	December 23
2018	December 16
2019	December 30
2022	January 6

concentrated in grassed areas within boulder fields and sites very close to these boulder fields (Green 2008).

The summer of 2019/2020 was unusual—the previous winter ski season was extended at Thredbo; snow fell through November/December; and fire started in the mountains in late December, with fire conditions later being

classified as 'Catastrophic' for the first time ever in this region. The impact of long-lying winter snow may have a profound negative impact on insect numbers (Green and Slatyer 2020). Late falls of snow, after an initial decline of winter snow, also may negatively impact numbers (Green 1997). The cause(s) of the crash appear to be very different from those that caused the crash in Bogong Moth numbers, which appears to have occurred before the moths arrived in the mountains (Green et al. 2021). Therefore, in the case of March flies, we must look at local causes such as snow cover, temperature and food resources.

Effects of snowmelt

Green (2010) described variations in the first flowering of Marsh Marigold *Caltha introloba* and Mueller's Snow-gentian *Gentianella muelleriana*, which significantly correlated with date of snowmelt, earliest arrival of Australian Pipits (as Richard's Pipits) *Anthus australis* and Bogong Moths, and latest arrival of Flame Robins *Petroica phoenicea*. In the same study, March flies did not respond to earlier or later snowmelt, with an almost unvarying emergence date in mid-December. There has been no change in the date of emergence since observations began (Fig. 3) and March flies at high elevation

on average appeared on day 344.7 (virtually on 10 December) (Fig.3). This supports Green's (2010) findings that March fly emergence is not affected by snowmelt.

The numbers of *C. maculiventris* present in the mountains during December 2019 did not seem to have changed. Snow Gum flowering (Table 3) occurs for about 3 weeks each year at a time suitable to provide a food resource for *C. maculiventris*, although in some years (such as 2020/2021) Snow Gums do not flower. At Charlotte Pass in December 2019, Snow Gums were not flowering on 13 December but were flowering on 30 December. However, this was no longer the case on our return to Charlotte Pass on 24 January 2020. Although it is mainly subalpine to montane, *C. maculiventris* is often found in the alpine zone and has been commonly recorded just below the treeline (Table 1). This species was also commonly found by us throughout lower elevations, and was recorded at Island Bend at 1200 m ASL until 31 December 2019, when KNP closed following the outbreak of extensive fires. *Dasybasis froggatti* is uncommon in subalpine areas, with just single individuals found, whereas *C. maculiventris* is readily found in numbers of ten or more (with

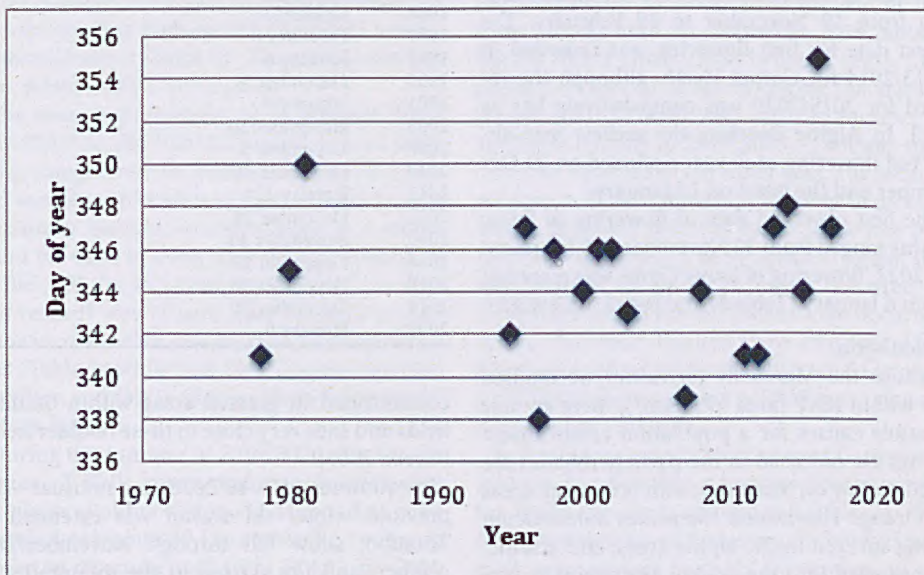


Fig. 3. The first date of emergence in March flies *Dasybasis froggatti*, recorded from 1979–2019.

one count of 21 for this study). By contrast, for *D. froggatti* in the alpine zone, 21 were counted on one occasion in 2013/14, and averages were as high as 18.5 flies per count in 2015/2016. A total of 9 days of counting in 2019/2020 resulted in observations of *D. froggatti* on only 4 days, with an average of 0.6 flies per count (Table 1).

Effects of temperature

The longevity of the winter snow was not indicative of an exceptional spring (Table 2). Heavy summer snow that affected insects was recorded by Green (1997). At lower altitudes, where insects had emerged for the summer, the snow reduced insect numbers without later recovery, whereas at higher altitudes, where winter snow persisted and insects had not yet emerged, the heavy summer snowfall did not affect insect numbers. However, March flies emerged on 10 December 1980 with 24 cm of snow falling at high altitudes a week later from 16 to 19 December but, on 12 January 1981, March flies were recorded in high numbers. Following the biggest winter snowfall on record at the Snowy Hydro snow course in 1981, heavy snow fell again, from 16 to 18 November in that year and again on 14 December. Snow was still present when March flies were recorded at high altitudes on 16 December 1981. Evidently, temperatures in these snowfall events (which were not long-lasting) generally had no impact on March fly survival.

In 2019, there was one record of -5.8°C and only 3 other days below 0°C in the first half of November (Bureau of Meteorology [BoM] Thredbo Top Station). Two days in December were below 0°C , the lower being -2.2°C (BoM Thredbo Top Station). These temperature conditions in this 2-month period would have had very little impact on fly numbers. In contrast, in the summer of 2019/2020 temperatures reached 24.5°C in December and 26.0°C (BoM Thredbo Top Station) in January, suggesting that maximum, rather than minimum, temperatures may have a greater impact on March flies.

Up to 2009, fires were measured using the McArthur Forest Fire Danger Index developed in the 1960s. This index traditionally measured the maximum degree of fire danger to a level of Extreme. However, after the Black Saturday

bushfires in 2009 the maximum level of the index was extended to the level Catastrophic. 2019 was Australia's hottest and driest year on record and in the summer of 2019/2020 fire danger in the alpine zone was classified as Catastrophic for the first time. This indicates 2019/2020 was a very unusual summer: no crash in March fly numbers had occurred in previous hot summers when fire danger was not at a Catastrophic level.

During the growing season, mean air temperature at the global high elevation tree limit is $6.4 \pm 0.7^{\circ}\text{C}$ (Körner and Paulsen, 2004; Körner, 2012). The corresponding Australian temperature at the treeline is 7.0°C , which is within the global mean range (Green and Stein 2015). These air temperatures correspond to soil temperatures shaded by dense vegetation (such as in uppermost forest patches). In the last 15 days of the previous warmest year in this study (2012/2013), the soil temperature averaged 8.28°C , whereas in 2019/2020 the average was 10.92°C , followed by 9.41°C in 2021/2022. Above the winter snowline and above ground, the 2 hottest months are January and February, with an average of 12.7°C and 11.4°C respectively over the past 12 years of recordings (Green et al. 2021). The highest temperature in that time was 15.7°C in 2019. However, in 2019/2020, above the ground at Bogong Moth sites for the first 15 and last 15 days of December, the mean hourly temperature over 24 hours ranged from 7.2°C to 15.6°C (Green et al. 2021). In January 2020, the average daily temperature for the first 5 days, including the Catastrophic-level day of 4 January, was even higher at 16.5°C . From the time of our return to KNP on 24 January, temperatures dropped to a 24-hour average of 10.3°C until the end of the month.

Effects of food resource availability

During the snow-free season in 2019/2020, there was a general belief among National Parks and Wildlife Service staff that there were few flowering plant species. Our results agree with their observations as only 16 species were recorded from snow-melt to 13 December 2019 (Table 2). A similar count was made by Casey Gibson (pers. comm. 2019) during the same period. We recorded 72 species for the

entire snow-free season in 2019/2020 but only 36 species were flowering from snow-melt to 30 December.

Snow Heath, which normally flowers at about the March fly emergence time, was not recorded flowering on 13 December 2019; flowering was recorded on 30 December 2019 but not later in the season. (Table 2). In previous years, first flowerings in Snow Heath were recorded mostly before 13 December. Alpine Baeckea was flowering on 30 December 2019 but this was only a single specimen. After the National Park was reopened, numbers of flowering plants were not plentiful until February. Carpet Heath was recorded flowering only from 24 January 2020 (Table 2). In previous years, first flowerings in Carpet Heath and Alpine Baeckea were recorded mostly after 30 December, usually after the end of January. Since Carpet Heath and Alpine Baeckea flowers were not common again until 2020, the hot conditions from mid-December 2019 until early January 2020 were probably unsuitable for flowering of these species, hence the lack of these plants as a food resource impacted *D. froggatti* numbers. This was not the case with *C. maculiventris* because Snow Gums were flowering heavily right down to Island Bend on the Snowy River and these March flies were a nuisance.

Flowering requires at least 2 steps of induction. The first step is the development of the primordial flower; the second step is the induction of the actual processes of flower development. If the winter had been too mild, some species may not have reached their chilling requirement for flower induction (Körner, pers. comm. 2020). However, these conditions were not evident, with soil temperature loggers recording sufficiently cool soil temperature for flower induction at the treeline from July to September over the 3 years 2017, 2018 and 2019, with annual hourly average temperatures of 1°C, 1.3°C and 1.2°C respectively (personal data KG). An opportunistic (just actual temperature-driven) non-photoperiod controlled flowering timing might have caused flowering much earlier in 2019/2020, with sparser flowering spread over a longer time period (Körner, pers. comm. 2020) thus thinning the food provision for pollinators. However, alpine plants were flowering by 7 October 2019, 30

September 2018 and 20 September 2016. In 2019, both numbers of species flowering (Table 2) and number of individuals flowering declined, with some species being represented by only one individual. It is likely that a mismatch between photoperiod and concurrent temperatures caused some hormonal disorder so that flowering did not occur (Körner, pers. comm. 2020).

In 2020/2021 there was an increase in plant species in flower from the end of the snow season until 31 December, with more than twice the number that were flowering the previous summer. At the same time there was an increase in numbers of *D. froggatti* to an average of 1.9 flies and a maximum of 2.6 flies per count, an improvement but still well below expectation.

The population of *D. froggatti* returned to a 'normal' number in the summer of 2021/22 with an average of 7 specimens and a maximum of 12 flies per count. Over a period of 17 days at Rawsons Pass (at the foot of Mount Kosciuszko) the average was 17.0 (Dan Nichols pers. comm. 2020).

D. froggatti is thought to have an annual life cycle (Fuller 1937; Green and Osborne 2012) so the decline in numbers and slow recovery over 2 years suggests that prolonged years of difficult summer conditions could impact the survival of this species, but in the event of a good year it can recover quickly.

Acknowledgements

Thanks to Eric Warrant and Bryan Lessard for discussion about the March flies and for reading the manuscript. Thank you to Christian Körner for discussions on the cause of the decline of flowering.

References

- BoM Thredbo Top Station < <http://www.bom.gov.au/places/nsw/thredbo-top-station/observations/thredbo-top-station/> [accessed 1 February 2019].
- Fuller ME (1937) Notes on the biology of *Tabanus froggatti*, *T. gentilis*, and *T. neobasalis* (Diptera). *Proceedings of the Linnean Society of N.S.W.* 62, 217–228.
- Green K (1997) Inter-annual, seasonal and altitudinal differences in invertebrate activity in the Snowy Mountains. *The Victorian Naturalist* 114, 222–229.
- Green K (2006) The effect of variation in snowpack on timing of bird migration in the Snowy Mountains. *Emu* 106, 187–192.
- Green K (2008) Migratory bogong moths (*Agrotis infusa*) transport arsenic and concentrate it to lethal effect by gregariously aestivating in alpine regions of the Snowy Mountains of Australia. *Arctic Antarctic and Alpine Research* 40, 74–80.
- Green K (2010) Alpine taxa exhibit differing responses to climate warming in the Snowy Mountains of Australia. *Journal of Mountain Science* 7, 167–175.

- Green K, Caley P, Baker M, Dreyer D, Wallace J and Warrent EJ (2021) The Australian Bogong moth (*Agrotis infusa*, Lepidoptera: Noctuidae) 1951–2020: Decline and crash. *Austral Entomology* 60, 66–81.
- Green K and Osborne WS (2012) *Field guide to wildlife of the Australian snow country*. (New Holland Publishers: Chatswood).
- Green K and Slatyer P (2020) Seasonal, interannual and decadal changes in arthropod community composition along an alpine elevational gradient in the Snowy Mountains of southeastern Australia. *Austral Ecology* 45, 144–157.
- Green K and Stein JA (2015) Modeling the thermal zones and biodiversity on the high mountains of Meganesia: the importance of local differences. *Arctic, Antarctic and Alpine Research* 47, 671–680.
- Inouye DW and Pyke GH (1988) Pollination biology of the Snowy Mountains of Australia: comparisons with montane Colorado, USA. *Australian Journal of Ecology* 13, 191–210.
- Körner C (2012) *Alpine Treelines—Functional Ecology of the Global High Elevation Tree Limits*. (Springer: Basel).
- Körner C and Paulsen J (2004) A world-wide study of high altitude treeline temperatures. *Journal of Biogeography* 31, 713–732.
- Mackerras IM (1956) *The Tabanidae (Diptera) of Australia*. 1. General review. *Australian Journal of Zoology* 4, 376–407.
- Mackerras IM (1960) *The Tabanidae (Diptera) of Australia*. 3. Subfamily Pangoniinae, Tribe Scionini and Supplement to Pangoniini. *Australian Journal of Zoology* 8, 1–152.

Received 23 July 2021; accepted 14 March 2022

The case of a Pygmy Hippopotamus *Choeropsis liberiensis* in the Northern Territory, Australia: extrapolating from a Colombian experience

Matthew Mo

PO Box A290, Sydney South, NSW 1232.
Email: <matthew.sk.mo@gmail.com>.

Abstract

A Pygmy Hippopotamus *Choeropsis liberiensis* shot in the Douglas–Daly district, Northern Territory, in 2009 is believed to have survived in the wild for up to 6 years following the closure of a private zoological facility. The situation bears resemblance to another in which Common Hippopotamuses *Hippopotamus amphibius* have become an invasive species in Colombia, following captive animals escaping from a closed exotic animal collection. Addressing this hippo population has been complicated by logistical challenges and public resistance to lethal management options. Non-lethal management options have been fraught with difficulties and practical limitations.

Parts of the Northern Territory are also likely to favour the survival of escaped hippos owing to the tropical climate and abundance of waterways and vegetation. Extrapolating from the numerous challenges in the Colombian experience, prevention of invasive hippos escaping in the first instance would be prudent. The presence of a Pygmy Hippopotamus in the Douglas–Daly district highlights the importance of accounting for all captive animals during closures of zoological facilities. (*The Victorian Naturalist* 139 (4), 2022, 103–111)

Keywords: Hippopotamidae, invasive species, naturalisation, ungulates, zoological facilities

Introduction

In large parts of the world, mammals have established invasive populations outside their natural range through deliberate introductions by humans (Fairfax 2019) or as escaped pets or livestock (Andersen 2008; Harrington et al. 2020). Amongst the large-bodied mammals, ungulates (Orders Artiodactyla and Perissodactyla) have a notable record for naturalising in extralimital regions. On the Australian continent, there are currently at least 15 species of introduced ungulates (Table 1), which include wildlife species as well as domesticated stock (Saalfeld and Edwards 2010; Davis et al. 2016;

Forsyth et al. 2018; Cripps et al. 2019). These animals were imported for 3 common purposes: as working and/or production animals (Bough 2006; Bengsen et al. 2017) or for the Acclimatisation movement, which attempted to render the Australian environment more similar to that of England by introducing non-native species (Moriarty 2004).

Invasive ungulate populations have been implicated in a range of environmental impacts, including overgrazing and trampling of native vegetation (Masters et al. 2018; Robertson et al. 2019), damage to trees from abrasion

Table 1. Introduced ungulate species in Australia.

Common name	Scientific name	Importation purpose	Reference
Order Artiodactyla			
Dromedary Camel	<i>Camelus dromedarius</i>	Working animal	McKnight (1969)
Domestic Pig	<i>Sus domesticus</i>	Production animal	Bengsen et al. (2017)
Chital Deer	<i>Axis axis</i>	Acclimatisation movement	Moriarty (2004)
Hog Deer	<i>Axis porcinus</i>	Acclimatisation movement	Moriarty (2004)
Red Deer	<i>Cervus elaphus</i>	Acclimatisation movement	Moriarty (2004)
Fallow Deer	<i>Dama dama</i>	Acclimatisation movement	Moriarty (2004)
Rusa Deer	<i>Rusa timorensis</i>	Acclimatisation movement	Moriarty (2004)
Sambar Deer	<i>Rusa unicolor</i>	Acclimatisation movement	Moriarty (2004)
Banteng	<i>Bos javanicus</i>	Production animal	Calaby (1975)
Asian Water Buffalo	<i>Bubalus arnee</i>	Production and working animal	Albrecht et al. (2009)
Domestic Cattle	<i>Bos taurus</i>	Production animal	Forsyth et al. (2018)
Domestic Goat	<i>Capra hircus</i>	Production animal	Moseby et al. (2020)
Domestic Sheep	<i>Ovis aries</i>	Production animal	Forsyth et al. (2018)
Order Perissodactyla			
Domestic Horse	<i>Equus caballus</i>	Working animal	Nimmo and Miller (2007)
Donkey	<i>Equus asinus</i>	Working animal	Bough (2006)

(Davis et al. 2016), soil erosion and compaction (Ostermann-Kelm et al. 2009; Davies et al. 2020), damage to aquatic habitats (Skeat et al. 1996), and associated impacts on native species (Pearson et al. 2018). These impacts have prompted exhaustive efforts to control invasive populations, which can be controversial depending on public perceptions of the species of ungulate (Nimmo and Miller 2007; Driscoll et al. 2019). Culling is used as an immediate means of removing animals from the environment (Bengsen and Sparkes 2016; Hampton et al. 2017; Burrows 2018), while contraception techniques have been trialled as a non-lethal alternative (Raiho et al. 2015).

Hippopotamuses (family Hippopotamidae) are the third largest land animals, comprising 2 extant species: the larger Common or Nile Hippopotamus *Hippopotamus amphibius* found in rivers, lakes and swamps across sub-Saharan Africa (Lewison and Pluháček 2017); and the smaller Pygmy Hippopotamus *Choeropsis liberiensis* (Fig. 1), which is confined to forests and swamps of Côte d'Ivoire, Guinea, Liberia, Sierra Leone and formerly Nigeria (Ransom et al. 2015). Being large-bodied, hippos are popular in zoological collections (Senn et al. 2014; Tennant et al. 2018) and captive specimens are housed in every populated continent (Snyder 2015; Measey et al. 2020). There is currently only one confirmed invasive population of hippopotamus (Lundgren et al. 2017); however,

there have been other cases of free-roaming hippos being found outside Africa.

A free-roaming hippopotamus in the Northern Territory

In November 2009, there was a report of a Pygmy Hippopotamus roaming in the Douglas-Daly district of the Northern Territory, 154 km south of Darwin (Cassey and Hogg 2015). The hippo was mistaken for a feral pig and subsequently shot (Fig. 2) by a shooter undertaking a night-time invasive animal control operation. While impossible to be certain where the hippo



Fig. 1. (above) Pygmy Hippopotamus pair housed in a zoological facility in Australia.

Fig. 2. (right) Newspaper article published in the Northern Territory News media outlet (Statham 2009). Courtesy of the Northern Territory News.



Wild web of intrigue

Hippo's demise just tip of iceberg

By LARINE STATHAM

It's a curious tale of a hippopotamus, a pig hunter, a millionaire property developer, a red faced government and now a game safari.

The accidental shooting of a rare African species of pygmy hippo in the Northern Territory Outback is not where the story begins. But it is the event that sparked peoples' imagination and raised the question: Whatever happened to the animals of Tipperary Wildlife Sanctuary?

Tales about herbivorous African, Indian and Mongolian wildlife thriving in the harsh NT Outback have long been shared among friends around a campfire.

Once considered by many to be more fable than fact, the stories were reignited by the discovery of a pygmy hippo (pictured above) in the Douglas Daly region, some 200km south of Darwin, last week.

A long way from its place of ancestral origin, the pygmy hippo's story bears remarkable similarity to that of Pablo Escobar, one of the world's most famous drug cartel criminals.

When Escobar was gunned down on the run the animals from his own personal menagerie in Columbia escaped.

Most of the animals were captured and taken to other zoos. But at least two of Escobar's hippos were left behind.

By 2007 the wild herd had grown to more than 18 head, and some of the hippos had even wandered off to establish new stomping grounds in the Amazon.

South America, until last week, had been the only

continent other than Africa where hippos were known to still live in the wild today.

Any hopes that Australia too could be added to that list have since been destroyed.

The fantasy of a mini African menagerie wandering freely in the Top End could not be further from the truth.

About 300 of the animals, including herds of critically endangered African scimitar horned oryx and addax, were sold to a hunting safari in the Northern Territory.

A small number of the more crowd-attracting animals were transferred to a zoo in far north Queensland.

Sadly, it is believed the remainder of Tipperary's 2000 animals suffered the same fate as Escobar and the pygmy hippo following two separate and yet equally intriguing legal battles.

Nico Courtney said he would not have shot the pygmy hippo had he known what it was.

Mr Courtney, 27, was out spotlight hunting with mates on November 12 when he shot what he thought was a pig.

"It's not really a trophy or something you would brag about, it makes me feel sick," he told reporters in Darwin.

"We got out and had a look at it and thought that's not a pig, it's a hippo."

"Then we thought you don't get hippos in Australia."

Mr Courtney went to bed hoping to reassess the situation in the daylight, but woke to find it was, in fact, still a pygmy hippo.

Mr Courtney took the carcass to the Douglas Daly Research Farm, where it was refrigerated for possible preservation.

Warren Anderson, the millionaire property developer who built the NT Parliament and established Tipperary Sanctuary in 1986, said the death of the hippo could be blamed solely on the Territory Government.

"I built that property up into a wonderful sanctuary for animals, our breeding programs were great, I had good men working for me and it all collapsed in a heap," Mr Anderson said.

"That Labor Government up there destroyed that wildlife park and you can lay the blame for the predicament these animals are in squarely on their shoulders."

Mr Anderson was accused of animal neglect for failing to adequately feed two of his rhinoceroses in 2003 and was subsequently arrested at gunpoint by police, but was later exonerated.

The Territory Government was forced to publicly

apologise and pay Mr Anderson an undisclosed sum of money.

"By then the damage had been done," he said. "The whole thing was a disaster."

Mr Anderson eventually tried to sell the animals and the property.

Mareeba Wild Animal Park in Queensland was to take most of the animals.

The deal hit difficulties when the Mareeba sanctuary was raided in March 2004 by the Australian Federal Police, investigators from the Queensland Department of Natural Resources, Mines and Energy and the RSPCA.

The owner of Mareeba, David Gill, fled back to the UK, leaving the pending transfers in limbo.

An Australian Regional Association of Zoological Parks and Aquariums (ARAZPA) offered to relocate the animals caught up in the legal dispute.

A spokesman for ARAZPA said a small number of animals were later successfully transferred to Mareeba Wild Animal Park, which has since been sold and is today known as the Cairns Wildlife Park.

However, the spokesman could not say how many were transferred, nor did he know where the other animals from Tipperary Wildlife Sanctuary had been sent.

"We have no animal inventory list for Tipperary because they were not a member of ARAZPA at the time," he said.

Mr Anderson said he did not know where the animals were now, but said some were still on the Tipperary property when he sold it.

"There was an array of wonderful animals there whatever happened to them. I don't know," he said.

"When I left, the people who had bought the animals had not yet taken them off the property."

"I don't know whether they collected them."

The current manager of Tipperary Station, Steve Dumsday, said there were no animals on the property when Allan Myers purchased the station to run cattle.

"The first we heard of it was with the shooting of the little hippo," he said.

Kevin Gleeson, the owner of Mary River Australian Safari, said he purchased about 20 of the animals from Mr Gill.

"I saved those animals by buying them," he said.

"I feel personally that most people turned their backs on the animals."

The International Union for

the Conservation of Nature says the scimitar horned oryx is extinct in the wild and efforts are under way to reintroduce it.

It is believed there are only a few thousand of them left in captivity around the world.

Mr Gleeson said the scimitar horned oryx herd had died in size since being transferred to his property, about 300km south of Darwin, and that none had been taken as trophies.

"I've got to be able to afford to feed and keep that animal, so sustainability is the key," he said.

"If you want to help an animal species survive today you've got to give it a value."

"I'm no different to the cattle farmers."

"If you said to me 'you can't sell that animal, you can't shoot that animal, well then I'd put up my hand and say 'I can't afford to feed them anymore'."

It costs Mr Gleeson about \$70,000 a year to feed the 2000 animals he has on his 330,000 acre property.

"Let me get those animals to a breeding stage where I have surplus, and then we will allow the hunters to take the surplus — the older animals that are no longer breeding — and then I can maintain the herd forever."

Mr Gleeson said he could dictate which animals could be killed by visiting hunters because they were always escorted by a guide.

"We hunt early in the morning and late in the afternoon, never at night because it's too hard to know what you are shooting at."

It is understood the Museum and Art Gallery of the Northern Territory has expressed an interest in having the pygmy hippo preserved by a taxidermist.



EXOTIC CREATURE: Kumba — thought to be the brother of the pygmy hippo shot at Douglas Daly this month — was one of four pygmy hippos moved to Tipperary Station from the Pearl Coast Zoo at Broome in 1991

originated from, its presence in the area was widely speculated to be associated with a private exotic animal collection that was formerly maintained on a pastoral lease named Tipperary Station (ABC News 2009; Betts 2009; Statham 2009) and closed in 2003. One media outlet (Thompson 2018) published a statement from a former worker that indicated the possibility of the hippo being a remaining animal not transferred to other facilities:

It was a terrific enclosure for the animals, but it did allow the smaller animals to be able to hide out. I don't know the exact situation but reading between the lines, I suspect that there was a calf that was missed that was either not known about or that they were unable to locate and assumed was dead. After all the animals were moved and the enclosure was turned back into a cattle enclosure, the animal then left and made its way down to the river.

If the hippo shot in November 2009 was an ex-captive animal from Tipperary Station, then it had survived in the wild for some years.

A statement from another local source published by Thompson (2018) alluded to a hippopotamus remaining present in its enclosure after the relocations were finalised:

Months and months later, someone who was keeping their pet dogs in the caged area there suddenly saw a hippo erupt from the water. Over time, a gate was left open or the fence deteriorated and it got out.

The same source also asserted that the hippopotamus was observed living free prior to the shooting:

Helicopter pilots would tell you that they would see it out in the wet areas and that kind of stuff, just roaming around, living a pygmy hippo life.

Invasive hippopotamuses in Colombia

The situation of a free-roaming hippo in the Northern Territory bears resemblance to the case of a naturalised Common Hippopotamus population in Colombia. Founder animals of the population were hippos imported into the country by drug baron Pablo Escobar and kept contained on a man-made lake on his private ranch estate, Hacienda Nápoles, until his death in December 1993 (Dembitzer 2018; Monsalve Buriticá and Ramírez Guerra 2018). The ranch estate, situated in Doradal, Magdalena, between Medellín and Bogotá, spans approximately 5000 acres. The first hippos were believed to be imported as juveniles in the 1980s (Monsalve Buriticá 2014)—

potentially up to 6 individuals (Valderrama Vásquez 2012), though some sources state only 2 individuals (Monsalve Buriticá 2014) or one male and 3 females (Dembitzer 2018). The hippos were probably sourced from zoological facilities in the United States of America (Measey et al. 2020). The herd successfully reproduced and grew in size (Measey et al. 2020).

Following Escobar's death, his exotic animals were either transported to other zoological facilities (Dembitzer 2018) or killed for food (Monsalve Buriticá and Ramírez Guerra 2018). The dangers and excessive costs of relocating hippos resulted in some remaining at Hacienda Nápoles. Some of the remaining hippos eventually escaped and reached the Magdalena River and smaller tributaries (Measey et al. 2020).

The size of the hippo population in Colombia is not known, though some sources have reported estimates of 10 to 30 individuals (Valderrama Vásquez 2012; Monsalve Buriticá 2014) or up to 80 individuals (Shurin et al. 2020). The current area occupied by the population is estimated to be approximately 2000 km² (Jiménez et al. 2018), though mature breeding individuals have been recorded more than 100 km from Hacienda Nápoles. Notable examples of long-distance dispersals include 3 hippos recorded in Puerto Berrío (~90 km north) in 2009, and an unknown number of hippos found in Ciénaga Barbacoas (105 km north) in 2013 (Subalusky et al. 2021). There was also an unconfirmed report of a hippo in Magangué Town, 370 km north of Hacienda Nápoles (Castelblanco-Martínez et al. 2021). If the sighting was genuine, it represents the northernmost sighting of a free-roaming hippo in Colombia.

Issues associated with invasive hippopotamus populations

Large herbivores are generally regarded as ecosystem engineers (Ripple et al. 2015). Studies have found that hippos moving through the environment can create paths that connect waterbodies or separate them if new paths fill with sediment following floods. Furthermore, the action of scouring, wallowing and compressing the bottom of rivers and ponds increases water retention in such waterbodies (Naiman and Rogers 1997). Thus, hippos alter hydrological

connectivity and local geomorphology (McCarthy et al. 1998; Mosepele et al. 2009). A recent study found that grazing by Common Hippopotamuses significantly reduces grass canopy height and the abundance and size of woody plants, and increases concentrations of some soil elements (McCauley et al. 2018). Conversely, their defecation in the water imports energy and nutrients from terrestrial systems to aquatic systems (McCauley et al. 2015; Subalusky et al. 2015). The ecological roles played by hippos in their natural ranges mean that their influence on the ecology and environment of extralimital areas is unlikely to be benign. While the environmental impacts of hippos in Colombia are still being assessed and quantified, scientists have postulated potential impacts such as habitat alteration, disruption of ecosystem processes, competition with native herbivores and destabilisation of environmental systems (Monsalve Buriticá 2014). In particular, hippos are expected to increase nutrient loading in waterways, with potential concentrations of water quality impacts in areas where groups aggregate (Subalusky et al. 2021).

Hippos also have negative socio-economic impacts when they feed on cultivated crops, attack livestock or prevent fishermen from using their usual fishing grounds (Valderrama Vásquez 2012; Kremer 2014; Capizzi et al. 2018; Measey et al. 2020). Media reports of surprise encounters with hippos also generate fears of these animals in communities (Corran 2020).

The breadth of these potential issues and impacts posed by the presence of hippos demonstrates the importance of implementing population control programs. However, Colombian Government management actions have caused controversy and have been met with public resistance. In 2009, a bull hippo posing a danger to communities was fatally shot, causing strong public backlash (Dembitzer 2018). This experience corresponds with a global trend in lack of community support for the killing of charismatic animals (Jarić et al. 2020). Disparity between public perceptions on the control of certain animal taxa is often associated with whether animals are held in high cultural or emotional regard (Nimmo and Miller 2007; Crowley et al. 2017, 2019), as opposed to whether they are perceived as food resources

or pests, e.g. goats (Heriot et al. 2019) or rodents (Pople et al. 2014; Parsons et al. 2017). In Colombia, hippos have become an iconic species and are strongly associated with the identity of Doradal; Hacienda Nápoles, now a theme park managed by the Municipality of Puerto Triunfo, continues to house a remaining captive herd as a tourist attraction (Measey et al. 2020), and the opportunity to see wild hippos in the surrounding area is perceived by local people as part of the region's heritage (Corran 2020). Some sections of the community have also benefited economically from tourists visiting to see free-roaming hippos and shopping at local businesses selling hippo-related souvenirs. The threatened status of the Common Hippopotamus (Lewison and Pluháček 2017) potentially also contributes to public opposition to shooting as a management option, though hippos in extralimital regions provide no direct benefit to the conservation of natural hippo populations. Relocating hippos to existing zoological facilities was considered logistically difficult when the animals were captive in Hacienda Nápoles (Dembitzer 2018), and thus less feasible as a management option for a free-roaming population. Although one young hippo was captured and rehomed to a zoological facility in Cundinamarca in 2018 (Montenegro et al. 2019), it has been estimated that capturing each adult hippo would cost up to 80 million Colombian pesos (equivalent to \$A27 664) and require 4 months to undertake (Semana 2009). Rehoming the entire population to captivity is also impractical due to zoological facilities being limited in their capacity to accept additional animals, a situation often not properly understood by individuals in the community (Monsalve Buriticá and Ramírez Guerra 2018).

Following the shooting of the bull hippo in 2009, legal action was taken to prevent any further culling. Castration of bull hippos was proposed as an alternative means of reducing the population (Montenegro et al. 2019). In March 2011, a bull was captured, castrated and transported by helicopter to Hacienda Nápoles (Valderrama Vásquez 2012); however, logistics and resources required for the operation were exhaustive. In 2016, two adult bulls were also successfully sterilised by veterinarians

(Restrepo Betancur et al. 2016); however, the costs of the procedures remained prohibitive for castration to provide a feasible management option for the entire population (Montenegro et al. 2019).

Discussion

There have been no further reports of Pygmy Hippopotamuses in the Northern Territory, suggesting the default assumption that the hippo shot in November 2009 was a lone individual, and thus incapable of reproducing. Nevertheless, the situation in Colombia demonstrates the invasion potential of hippos. The naturalisation of hippos in Colombia appears to correspond with favourable factors such as continuous water availability, latitude corresponding to their natural range (5.83°N to 9.10°N), abundant food resources and an absence of natural predators (Dembitzer 2018; Montenegro et al. 2019). The Douglas–Daly district is likewise abundant in waterways and vegetation (Hutley et al. 2011; Fig. 3) and has a tropical climate (13.86°S) like the natural range of the Pygmy Hippopotamus (4.61°S–8.11°S). In contrast to the Colombian situation, Saltwater Crocodiles *Crocodylus porosus* occur in the Northern Territory and would likely provide some predation pressure, judging from known instances

of crocodiles taking larger ungulates (Adame et al. 2018). Nevertheless, the discovery of the Pygmy Hippopotamus roaming in the Douglas–Daly district some years after closure of the exotic animal collection at Tipperary Station provides evidence that such a species is capable of persisting in the region.

Studies of hippos in the wild are mostly limited to the Common Hippopotamus (Flacke et al. 2015; Snyder 2015). The Common Hippopotamus has high rates of reproduction and population growth in its natural range (Martin 2005), which corresponds with the successful establishment of this species in Colombia: a recent review predicted that this population could reach 400 to 800 individuals by 2050 (Subalusky et al. 2021). Conversely, information on the reproductive biology of the Pygmy Hippopotamus is poor and entirely limited to observations of captive individuals (Flacke et al. 2015). Based on limited knowledge, it is known that Pygmy Hippopotamuses reach sexual maturity at 3 to 4 years of age and are reproductive for at least 25 years (Flacke et al. 2015). The species is non-seasonally polyestrous, demonstrated by births in captivity occurring throughout the year in both southern and northern hemispheres

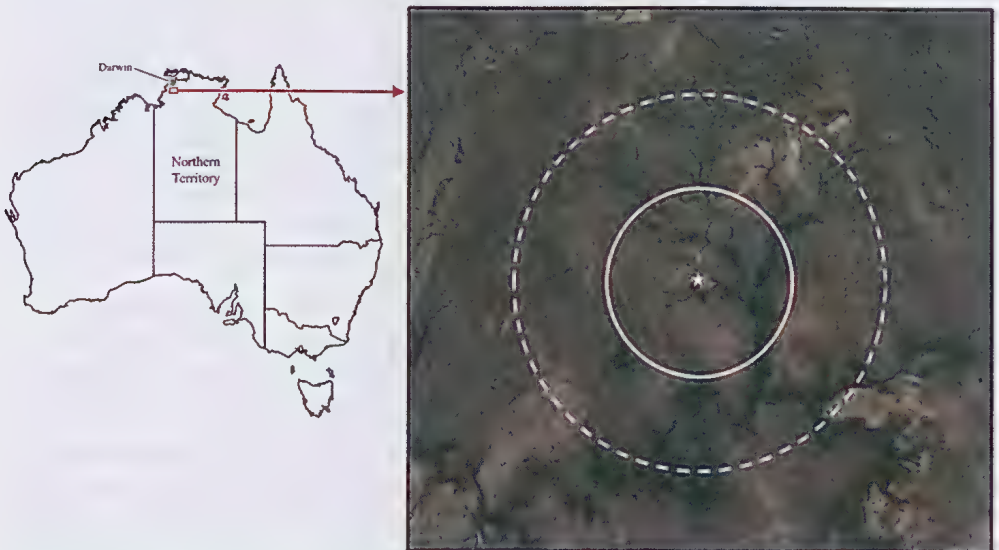


Fig. 3. Satellite aerial photograph showing waterways and associated vegetation within 10 km (unbroken line) and 20 km (broken line) of Tipperary Station, Douglas–Daly district, Northern Territory.

(Steck 2016; Flacke et al. 2017). However, reproductive success in captive breeding pairs is highly variable; some breeding pairs have reproduced readily while others repeatedly fail to reproduce even when estrous behaviour and mating is observed regularly and/or pregnancies occur (Flacke et al. 2015; Steck 2016). It is therefore difficult to speculate on potential reproductive success in a scenario where a group of Pygmy Hippopotamuses consisting of both sexes escape into the wild.

If a hippo population were to establish in the Northern Territory, it would be distinctive amongst Australia's invasive ungulates, which have all been introduced through the common pathways of working and production animals being released, and acclimatisation (Table 1). Elsewhere, invasive species have been known to establish populations derived from animals that have escaped from zoological facilities (Hulme et al. 2008; Pauza et al. 2014). However, a study providing a quantitative appraisal of invasion risks from vertebrate species escaping from Australian zoological facilities concluded that risks were extremely low (Cassey and Hogg 2015), though the study focused on established facilities rather than facilities undergoing closure. The case of the Pygmy Hippopotamus in the Douglas–Daly district highlights the importance of accounting for all animals during closures of zoological facilities. At present, there are only five individuals in the Australian captive population of Pygmy Hippopotamuses (Steck and Pagan 2022), so the likelihood of an individual escaping or being unaccounted for is extremely low.

As experienced in Colombia, addressing invasive hippo populations is complicated and is hindered, in many cases, by the social dimensions of the issue. Despite probable ecological and socio-economic impacts of invasive hippo populations (Subalusky et al. 2021), the removal of hippos is often contentious (Dembitzer 2018) owing to public sensitivities and negative emotions associated with wildlife killing (Jacobs et al. 2014; Jarić et al. 2020). When it comes to culling charismatic and/or familiar invasive species, conflicts between wildlife managers and the general public are not uncommon. Notable examples elsewhere include strong public opposition towards culling

free-roaming Domestic Horses *Equus caballus* in Australia (Driscoll et al. 2019; Nimmo and Miller 2007) and Grey Squirrels *Sciurus carolinensis* in Britain and Italy (Bertolino and Genovesi 2003; Lioy et al. 2019). When culling is not an option, wildlife managers may consider live capture for relocation to captivity (Valderama Vásquez 2012) or castration (Montenegro et al. 2019); however, the large size of hippos creates logistical and financial difficulties (Semana 2009), and in vast remote areas like the Douglas–Daly district, locating escaped hippos is likely to be difficult. The issues associated with invasive hippo populations highlight the importance of avoiding such invasions in the first instance.

References

- ABC News (2009) NT man shoots Pygmy Hippo by mistake. ABC News, 16 November 2009. Available from <<https://www.abc.net.au/news/2009-11-16/nt-man-shoots-pygmy-hippo-by-mistake/1145336>> [accessed 1 January 2022].
- Adame MF, Jardine TD, Fry B, Valdez D, Lindner G, Nadjji J and Bunn SE (2018) Estuarine Crocodiles in a tropical coastal floodplain obtain nutrition from terrestrial prey. *PLoS ONE* 13, e0200983.
- Albrecht G, McMahon CR, Bowman DMJS and Bradshaw CJA (2009) Convergence of culture, ecology, and ethics: management of feral Swamp Buffalo in northern Australia. *Journal of Agricultural and Environmental Ethics* 22, 361–378.
- Andersen MC (2008) The roles of risk assessment in the control of invasive vertebrates. *Wildlife Research* 35, 242–248.
- Bengsen AJ and Sparkes J (2016) Can recreational hunting contribute to pest mammal control on public land in Australia? *Mammal Review* 46, 297–310.
- Bengsen AJ, West P and Krull CR (2017) Feral Pigs in Australia and New Zealand: range, trend, management and impacts of an invasive species. In *Ecology, Conservation and Management of Wild Pigs and Peccaries*, pp. 325–338. Eds M Melletti and E Meijaard. (Cambridge University Press: Cambridge, United Kingdom).
- Bertolino S and Genovesi P (2003) Spread and attempted eradication of the Grey Squirrel (*Sciurus carolinensis*) in Italy, and consequences for the Red Squirrel (*Sciurus vulgaris*) in Eurasia. *Biological Conservation* 109, 351–358.
- Betts A (2009) Pygmy Hippopotamus shot during Northern Territory hunting trip. *Northern Territory News*, 16 November 2009. <https://www.ntnews.com.au/article/2009/11/16/101241_ntnews.html> [accessed 1 January 2022].
- Bough J (2006) From value to vermin: a history of the Donkey in Australia. *Australian Zoologist* 33, 388–397.
- Burrows ND (2018) Feral animals in the semi-arid and arid regions of Australia: origins, impacts and control. In *On the Ecology of Australia's Arid Zone*, pp. 331–373. Ed H Lambers. (Springer: Cham, Switzerland).
- Calaby JH (1975) Introduction of Bali Cattle to northern Australia. *Australian Veterinary Journal* 51, 108.
- Capizzi D, Monaco A, Genovesi P, Scalera R and Carnevali L (2018) Impact of alien mammals on human health. In *Invasive Species and Human Health*, pp. 130–150. Eds G Mazza and E Tricarico. (CAB International: Oxfordshire, United Kingdom).

- Cassey P and Hogg CJ (2015) Escaping captivity: the biological invasion risk from vertebrate species in zoos. *Biological Conservation* **181**, 18–26.
- Castelblanco-Martínez DN, Moreno-Arias RA, Velasco JA, Moreno-Bernal JW, Restrepo S, Noguera-Urbano EA, Baptiste MP, García-Loaiza LM and Jiménez G (2021) A hippo in the room: predicting the persistence and dispersion of an invasive mega-vertebrate in Colombia, South America. *Biological Conservation* **253**, 108923.
- Corran D (2020) Colombians grapple with a big problem: wandering hippos. ABC News, 24 February 2020. <<https://abcnews.go.com/International/wireStory/colombians-grapple-big-problem-wandering-hippos-69162939>> [accessed 1 January 2022].
- Cripps J, Pacioni C, Scroggie MP, Woolnough AP and Ramsey DS (2019) Introduced deer and their potential role in disease transmission to livestock in Australia. *Mammal Review* **49**, 60–77.
- Crowley SL, Hinchliffe S and McDonald RA (2017) Conflict in invasive species management. *Frontiers in Ecology and the Environment* **15**, 133–141.
- Crowley SL, Hinchliffe S and McDonald RA (2019) The park-keeper protectors: understanding opposition to introduced species management. *Journal of Environmental Management* **229**, 120–132.
- Davies C, Wright W, Hogan FE and Davies H (2020) Detectability and activity patterns of Sambar Deer (*Rusa unicolor*) in Baw Baw National Park, Victoria. *Australian Mammalogy* **42**, 312–320.
- Davis NE, Bennett A, Forsyth DM, Bowman DMJS, Lefroy EC, Wood SW, Woolnough AP, West P, Hampton JO and Johnson CN (2016) A systematic review of the impacts and management of introduced deer (family Cervidae) in Australia. *Wildlife Research* **43**, 515–532.
- Dembitzer J (2018) The case of hippos in Colombia. *Israel Journal of Ecology and Evolution* **63**, 5–8.
- Driscoll DA, Worboys GL, Hugh A, Banks SC, Beeton NJ, Cherubin RC, Doherty TS, Finlayson CM, Green K, Hartley R, Hope G, Johnson CN, Lintermans M, Mackey B, Paull DJ, Pittock J, Porfirio LL, Ritchie EG, Sato CF, Scheele BC, Slattery DA, Venn S, Watson D, Watson M and Williams RM (2019) Impacts of Feral Horses in the Australian Alps and evidence-based solutions. *Ecological Management and Restoration* **20**, 63–72.
- Fairfax RJ (2019) Dispersal of the introduced Red Fox (*Vulpes vulpes*) across Australia. *Biological Invasions* **21**, 1259–1268.
- Flacke GL, Chambers BK, Martin GB and Paris MCJ (2015) The Pygmy Hippopotamus *Choeropsis liberiensis* (Morton, 1849): bringing to light research priorities for the largely forgotten, smaller hippo species. *Der Zoologische Garten* **84**, 234–265.
- Flacke GL, Schwarzenberger F, Penfold LM, Walker SL, Martin GB, Millar RP and Paris MCJ (2017) Characterizing the reproductive biology of the female Pygmy Hippopotamus (*Choeropsis liberiensis*) through non-invasive endocrine monitoring. *Theriogenology* **102**, 126–138.
- Forsyth DM, Latham ADM, Davis NE, Caley P, Letnic M, Moloney PD, Woodford LP and Woolnough AP (2018) Interactions between Dingoes and introduced wild ungulates: concepts, evidence and knowledge gaps. *Australian Mammalogy* **41**, 12–26.
- Hampton JO, Edwards GP, Cowled BD, Forsyth DM, Hyndman TH, Perry AL, Miller CJ, Adams PJ and Collins T (2017) Assessment of animal welfare for helicopter shooting of Feral Horses. *Wildlife Research* **44**, 97–105.
- Harrington LA, Birks J, Chanin, P and Tansley D (2020) Current status of American Mink *Neovison vison* in Great Britain: a review of the evidence for a population decline. *Mammal Review* **50**, 157–169.
- Heriot S, Asher J, Williams MR and Moro D (2019) The eradication of ungulates (sheep and goats) from Dirk Hartog Island, Shark Bay World Heritage Area, Australia. *Biological Invasions* **21**, 1789–1805.
- Hulme PE, Bacher S, Kenis M, Klotz S, Kühn I, Minchin D, Nentwig W, Olenin S, Panov V, Pergl J, Pyšek P, Roques A, Sol D, Sölarz W and Vilà M (2008) Grasping at the routes of biological invasions: a framework for integrating pathways into policy. *Journal of Applied Ecology* **45**, 403–414.
- Hutley LB, Beringer J, Isaac PR, Hacker JM and Cernusak LA (2011) A sub-continental scale living laboratory: spatial patterns of savanna vegetation over a rainfall gradient in northern Australia. *Agricultural and Forest Meteorology* **151**, 1417–1428.
- Jacobs MH, Vaske JJ, Dubois S and Fehres P (2014) More than fear: role of emotions in acceptability of lethal control of wolves. *European Journal of Wildlife Research* **60**, 589–598.
- Jarić I, Courchamp F, Correia RA, Crowley SL, Essl F, Fischer A, González-Moreno P, Kalinkat G, Lambin X, Lenzen B, Meinard Y, Mill A, Musseau C, Novoa A, Pergl J, Pyšek P, Pyšková K, Robertson P, von Schmalensee M, Shackleton RT, Stefansson RA, Štajerová K, Verissimo D and Jeschke JM (2020) The role of species charisma in biological invasions. *Frontiers in Ecology and the Environment* **18**, 345–353.
- Jiménez G, Echeverri Lopez D, Baptiste M, Isaacs-Cubides PJ, García Loaiza LM, Noguera-Urbano E, Olaya-Rodríguez M, Velásquez-Tibata J and Moreno W (2018) Hipopótamos en Colombia. In *Biodiversidad 2018. Estado y Tendencias de la Biodiversidad Continental de Colombia*, pp. 205–206. Eds LA Moreno, GI Andrade and MF Gómez. (Instituto de Investigación de Recursos Biológicos Alexander von Humboldt: Bogotá, Colombia).
- Kremer W (2014) Pablo Escobar's hippos: a growing problem. BBC News, 26 June 2014. <<https://www.bbc.com/news/magazine-27905743>> [accessed 1 January 2022].
- Lewison R and Pluháček J (2017) *Hippopotamus amphibius*. The IUCN Red List of Threatened Species 2017: e.T10103A18567364. <<https://www.iucnredlist.org/species/10103/18567364>> [accessed 1 January 2022].
- Lioy S, Marsan A, Balduzzi A, Wauters LA, Martinoli A and Bertolino S (2019) The management of the introduced Grey Squirrel seen through the eyes of the media. *Biological Invasions* **21**, 3723–3733.
- Lundgren EJ, Ramp D, Ripple WJ and Wallach AD (2017) Introduced megafauna are rewiring the Anthropocene. *Ecography* **40**, 1–10.
- Martin RB (2005) Transboundary Species Project: Hippopotamus. Ministry of Environment and Tourism, Windhoek, Namibia.
- Masters P, Markopoulos N, Florance B and Southgate R (2018) The eradication of Fallow Deer (*Dama dama*) and Feral Goats (*Capra hircus*) from Kangaroo Island, South Australia. *Australasian Journal of Environmental Management* **25**, 86–98.
- McCarthy TS, Ellery WN and Bloem A (1998) Some observations on the geomorphological impact of Hippopotamus (*Hippopotamus amphibius* L.) in the Okavango Delta, Botswana. *African Journal of Ecology* **36**, 44–56.
- McCauley DJ, Dawson TE, Power ME, Finlay JC, Ogada M, Gower DB, Caylor K, Nyirya WD, Githaiga JM, Nyunja J, Joyce FH, Lewison RL and Brashares JS (2015) Carbon stable isotopes suggest that Hippopotamus-vectored nutrients subsidize aquatic consumers in an East African river. *Ecosphere* **6**, art52. <<https://doi.org/10.1890/ES14-00514.1>>
- McCauley DJ, Graham SI, Dawson TE, Power ME, Ogada M, Nyirya WD, Githaiga JM, Nyunja J, Hughey LF and Brashares JS (2018) Diverse effects of the Common Hippopotamus on plant communities and soil chemistry. *Oecologia* **188**, 821–835.
- McKnight TL (1969) *The Camel in Australia*. (Melbourne University Press: Melbourne).

- Measey J, Robinson TB, Kruger N, Zengeya TA and Hurley BP (2020) South Africa as a donor of alien animals. In *Biological Invasions in South Africa*, pp. 787–830. Eds BW van Wilgen, J Measey, DM Richardson, JR Wilson and TA Zengeya. (Springer: Cham, Switzerland).
- Monsalve Buritica S (2014) Los Hipopótamos (*Hippopotamus amphibius*) en Colombia. Especie exótica, introducida e invasora. *Revista Lasallista de Investigación* 11, 229–230.
- Monsalve Buritica S and Ramirez Guerra A (2018) Current status of Hippos (*Hippopotamus amphibius*) in Colombia: 2018. *CES Medicina Veterinaria y Zootecnia* 13, 338–346.
- Montenegro OL, López-Arévalo HF, Mora-Beltrán C, Lizcano DJ, Serrano H, Mesa E and Bonilla-Sánchez A (2019) Tropical ungulates of Colombia. In *Ecology and Conservation of Tropical Ungulates in Latin America*, pp. 157–195. Ed S Gallina-Tessaro. (Springer: Cham, Switzerland).
- Moriarty A (2004) The liberation, distribution, abundance and management of wild deer in Australia. *Wildlife Research* 31, 291–299.
- Moseby KE, Read JL and Andersen GE (2020) Goat movement patterns inform management of Feral Goat populations in semiarid rangelands. *Wildlife Research* 48, 44–54.
- Mosepele K, Moyle PB, Merron GS, Purkey DR and Mosepele B (2009) Fish, floods, and ecosystem engineers: aquatic conservation in the Okavango Delta, Botswana. *BioScience* 59, 53–64.
- Naiman RJ and Rogers KH (1997) Large animals and system level characteristics in river corridors. *BioScience* 47, 521–529.
- Nimmo DG and Miller KK (2007) Ecological and human dimensions of management of Feral Horses in Australia: a review. *Wildlife Research* 34, 408–417.
- Ostermann-Kelm SD, Atwill EA, Rubin ES, Hendrickson LE and Boyce WM (2009) Impacts of Feral Horses on a desert environment. *BMC Ecology* 9, 22.
- Parsons MH, Banks PB, Deutsch MA, Corrigan RF and Munshi-South J (2017) Trends in urban rat ecology: a framework to define the prevailing knowledge gaps and incentives for academia, pest management professionals (PMPs) and public health agencies to participate. *Journal of Urban Ecology* 3, jux005.
- Paauw M, Richley J, Robinson S and Fearn S (2014) Surviving in the south: a recent incursion of the Agile Wallaby (*Macropus agilis*) in Tasmania. *Australian Mammalogy* 36, 95–98.
- Pearson DJ, Neaves LE, Paxman M, Desmond A, Renwick J, Halley M, Willers N and Eldridge MDB (2018) Identification of a remnant population of the Black-flanked Rock-wallaby (*Petrogale lateralis lateralis*) in Kalbarri National Park, Western Australia, and implications for its management. *Australian Mammalogy* 41, 196–204.
- Pople A, Scanlan J, Cremasco P and Farrell J (2014) Population dynamics of House Mice in Queensland grain-growing areas. *Wildlife Research* 40, 661–674.
- Raiho AM, Hooten MB, Bates S and Hobbs NT (2015) Forecasting the effects of fertility control on overabundant ungulates: White-tailed Deer in the National Capital Region. *PLoS ONE* 10, e0143122.
- Ransom C, Robinson PT and Collen B (2015) *Choeropsis liberiensis*. The IUCN Red List of Threatened Species 2015: e.T10032A18567171. <<https://www.iucnredlist.org/species/10032/18567171>> [accessed 1 January 2022].
- Restrepo Betancur G, Varela Giraldo E and Usuga Suarez A (2016) Evaluation of epididymal spermatic quality of Hippopotamus *Hippopotamus amphibius* (Artiodactyla: Hippopotamidae) located in the Colombian Middle Magdalena. *Acta Zoológica Mexicana* 32, 158–167.
- Ripple WJ, Newsome TM, Wolf C, Dirzo R, Everatt KT, Galletti M, Hayward MW, Kerley GIH, Levi T, Lindsey PA, Macdonald DW, Malhi Y, Painter LE, Sandom CJ, Terborgh J and Van Valkenburgh B (2015) Collapse of the world's largest herbivores. *Scientific Advances* 1, e1400103.
- Robertson G, Wright J, Brown D, Yuen K and Tongway D (2019) An assessment of Feral Horse impacts on treeless drainage lines in the Australian Alps. *Ecological Management and Restoration* 20, 21–30.
- Saalfeld WK and Edwards GP (2010) Distribution and abundance of the Feral Camel (*Camelus dromedarius*) in Australia. *The Rangeland Journal* 32, 1–9.
- Semana (2009) Hay que reducir o anular los hipopótamos en Colombia. Semana, 1 September 2009. <<https://www.semana.com/nacion/medio-ambiente/articulo/hay-reducir-anular-hipopotamos-colombia/106952-3>> [accessed 1 January 2022].
- Senn H, O'Donoghue P, McEwing R and Ogden R (2014) Hundreds of SNPs for the endangered Pygmy Hippopotamus (*Choeropsis liberiensis*). *Conservation Genetics Resources* 6, 535–538.
- Shurin JB, Aranguren-Riaño N, Negro DD, Lopez DE, Jones NT, Laverde-R O, Neu A and Ramos AP (2020) Ecosystem effects of the world's largest invasive animal. *Ecology* 101, e02991.
- Skeat AJ, East TJ and Corbett LK (1996) Impact of feral Water Buffalo. In *Landscape and Vegetation Ecology of the Kakadu Region, Northern Australia*, pp. 155–177. Eds CM Finlayson and I Von. (Oertzen Springer: Dordrecht, The Netherlands).
- Snyder KD (2015) The Common Hippopotamus in the wild and in captivity: conservation for less charismatic species. *Journal of International Wildlife Law and Policy* 18, 337–354.
- Statham L (2009) Wild web of intrigue: hippo's demise just tip of iceberg. *Northern Territory News*, 28 November 2009.
- Steck B (2016) *International Studbook for the Pygmy Hippopotamus*. 22nd edition. (Zoo Basel: Basel, Switzerland).
- Steck B and Pagan O (2022) *International Studbook for the Pygmy Hippopotamus*. 28th edition. (Zoo Basel: Basel, Switzerland).
- Subalussy AL, Anderson EP, Jiménez G, Post DM, Lopez DE, García-R S, Nova León LJ, Parrish JFR, Rojas A, Solari S and Jiménez-Segura LZ (2021) Potential ecological and socio-economic effects of a novel megaherbivore introduction: the Hippopotamus in Colombia. *Oryx* 55, 105–113.
- Subalussy AL, Dutton CL, Rosi-Marshall EJ and Post DM (2015) The Hippopotamus conveyor belt: vectors of carbon and nutrients from terrestrial grasslands to aquatic systems in sub-Saharan Africa. *Freshwater Biology* 60, 512–525.
- Tennant KS, Segura VD, Morris MC, Snyder KD, Bocian D, Maloney D and Maple TL (2018) Achieving optimal welfare for the Nile Hippopotamus (*Hippopotamus amphibius*) in North American zoos and aquariums. *Behavioural Processes* 156, 51–57.
- Thompson J (2018) What happened to the exotic African animals that once roamed an outbreak cattle station? ABC Radio Darwin, 13 November 2018. <<https://www.abc.net.au/news/2018-11-13/curious-darwin-tipperary-station-wildlife-sanctuary-animals/10482880>> [accessed 1 January 2022].
- Valderrama Vásquez CAV (2012) Wild hippos in Colombia. *Aliens: The Invasive Species Bulletin* 32, 8–12.

Received 31 March 2022; accepted 23 June 2022

Diet of the Yellow-footed Antechinus *Antechinus flavipes*

Alan York¹, Amanda Ashton² and Julian Di Stefano¹

¹School of Ecosystem and Forest Sciences, The University of Melbourne, 4 Water Street, Creswick, Victoria 3363.

²Department of Environment, Land, Water and Planning, Level 1, 402 Mair Street, Ballarat, Victoria 3350.

Corresponding author: <alan.york@unimelb.edu.au>.

Abstract

The Yellow-footed Antechinus *Antechinus flavipes* is a widespread dasyurid marsupial living in a range of habitats in eastern and south-western Australia. Little is known of its diet; however, based on limited studies and anecdotes, it is thought to be a generalist carnivore. From a micro-histological study of scats from 25 animals in south-western Victoria, we found that while *A. flavipes*' diet consisted primarily of invertebrates, it also included considerable plant and some fungal material. Substantial variation in diet between individuals suggested that, like other species of the genus *Antechinus*, *A. flavipes* is most likely a generalist and opportunistic feeder, taking a wide range of food items, probably in response to their availability during individual foraging events. (*The Victorian Naturalist* 139 (4), 2022, 112–116)

Keywords: fire, micro-histological, scat, diet

Introduction

The Yellow-footed Antechinus *Antechinus flavipes*, also known as the Mardo, is a small (20–75 g) dasyurid marsupial that occurs in a range of environments in eastern and south-western Australia. Three subspecies are recognised, each geographically isolated (Wakefield and Warneke 1967): *A. flavipes flavipes* Waterhouse 1838 (south-eastern Queensland, NSW, Victoria and South Australia), *A. f. rubeculus* Van Dyck 1982 (north-eastern Queensland) and *A. f. leucogaster* Gray 1841 (south-western Western Australia). *Antechinus flavipes* is the most widespread member of its genus, occupying a variety of habitats, including arid shrubland and sclerophyll forest. In the north of its range, it also inhabits coastal heaths, swamps and woodland; in the far north, it is found in tropical vine forest (Christensen and Kimber 1975; Lada et al. 2007; Menkhorst 1995; Watt 1997). Some populations are listed as locally common, others as uncertain (Dickman 1980; Kelly 2006; Lada et al. 2008; Stokes et al. 2004).

The species is generally considered to be carnivorous, feeding primarily on a range of arthropods gleaned from leaf litter, logs, tree trunks and stumps, with nectar, pollen and small vertebrates taken opportunistically (Fleay 1949; Goldingay 2000; Hackett and Goldingay 2001). From an analysis of the gut contents of the Western Australian subspecies, Hindmarsh and Majer (1977) and Majer (1978) found that it ate a wide range of invertebrates of which

spiders, cockroaches, beetles and Hymenoptera (excluding ants) were the most abundant. They found no evidence of plant material and concluded that it is an opportunistic carnivore, with its gut contents reflecting the relative abundance of food groups in the environment.

The work reported here forms part of a broader study investigating the effects of fire on small mammal assemblages in the heathlands and woodlands of south-western Victoria (Di Stefano et al. 2011, 2014; Delaney et al. 2021; Nalliah et al. 2022). We investigated the diet of the Yellow-footed Antechinus *A. f. flavipes* using micro-histological analysis of scats collected during trapping. Owing to the relatively small number of individuals caught, we report the dietary analysis without attempting to interpret the results in the context of past fire history.

Methods

The study area was a 14 300 ha patch of unfragmented *Eucalyptus* woodland located within Drajurk and Nangeela State Forests near the town of Casterton in south-western Victoria, (37°35'S, 141°12'E). Approximately 60% of the study area is classified as Heathy Woodland (Department of Sustainability and Environment 2004), which is dominated by Brown and Desert Stringybark *Eucalyptus baxteri* and *E. arenacea*, Grass Trees *Xanthorrhoea australis* and *X. caespitosa*, and a range of heathy shrubs, grasses and forbs (Duff et al. 2013). The remaining area consists of grassy woodland, wet heath

or wetland, and was excluded from the study. The low-lying terrain is relatively flat (7–90 m ASL), and soils are deep, highly leached, acidic, fine to medium grained Aeolian quartz sand with little organic matter (Land Conservation Council 1972). The climate is generally mild, with mean annual minimum and maximum temperatures of 8.3°C and 20°C respectively, and an average annual precipitation of 656 mm (Bureau of Meteorology [BoM] 2022).

Details of the sampling design are fully described in Di Stefano et al. (2011, 2014). In summary, twenty 2.25 ha sites were chosen across a range of time since fire ages (2–68 years) using a stratified random protocol. Within each site, we defined 50 trapping locations at the intersections of a randomly positioned 25 m × 25 m grid. Trapping occurred for 5 consecutive nights at each site during winter (June) and spring (October) 2007, constituting a total of 5000 trap nights in each season. At each trapping location described above we placed a small Elliott trap (33 cm × 10 cm × 10 cm) baited with a mixture of oats, peanut butter and golden syrup. We marked each captured animal with a permanent marking pen and recorded species, weight, sex, and body length from nose tip to tail base.

Antechinus faecal material was collected from the traps on the first capture of each individual and stored in 70% ethanol. We did not collect faecal material obviously contaminated with bait, which could be identified by its colour. From the 20 study sites, and over the 2 sampling times (winter and spring 2007), we collected samples from 25 Yellow-footed *Antechinus*.

In the lab, samples were processed following Norbury (1988). First, faecal material was thoroughly mixed and washed through an 80 µm sieve with 125 ml of distilled water. The sample was then soaked in household bleach (4% sodium hypochlorite) for one hour, rinsed, and stained with 1% aqueous methyl violet for one minute. Samples were then mounted on a microscope slide with a few drops of glycerol, and cover slips sealed with nail varnish. Slides were viewed at 10–40 × magnification with an Olympus BX 41 compound microscope and sampled systematically using the intersections of a 2 × 2 mm grid. We attempted to identify 150 food items per sample on the basis of

micro-histological features (e.g. Storr 1961), with the food item closest to each grid point selected for identification.

We categorised each food item using 10 broad groups: monocotyledon, forbs (small herbaceous plants), heath (shrubs belonging to the Epacridaceae family), shrubs (non-heathy shrubs), trees, flowers, seeds, invertebrates, fungi and unknown. Food items were placed into groups with the aid of reference slides prepared from plant and invertebrate collections previously sampled from the study site. Because different rates of identification between food groups can lead to bias in samples with large numbers of unidentified fragments, we applied the correction described by Norbury (1988). This involved (a) collecting foliage samples from the study area, (b) using them to prepare a third set of slides representing each food group containing fragments with the same size class distribution as those in faecal samples, (c) from these new slides calculating the proportion of identifiable fragments in each food group and (d) using these data to adjust the original counts. Essentially, this method redistributes unidentified plant material to other food groups based on the relative capacity to identify fragments in each group, reducing the total number of groups to 9 (Fig. 1, Table 1).

Results

Despite 5000 trap nights across 20 sites in each season, capture rates were extremely low, both in spring (7) and winter (18); representing an overall rate of 0.25%. Eighteen of the 25 samples were from mature (17–24 years post fire) woodland, with 4 from older (68 years post fire) sites and 3 from younger (2–9 years post fire) sites. With such low numbers of individuals, it is not possible to reliably test hypotheses regarding the effect of sex or time since fire on *Antechinus* diet. The data are sufficient, however, to describe, in general terms, overall trends in spring and winter (Fig 1, Table 1). As predicted, the majority (mean = 53.1%) of diet items were of invertebrate origin with no evidence of a seasonal difference (independent t-tests, $P > 0.05$). Flowers and seeds together comprised 19.2% of food items, while fungi formed 4.5% of food items. Other vascular plant parts made up 23.3% of the diet. A striking result was

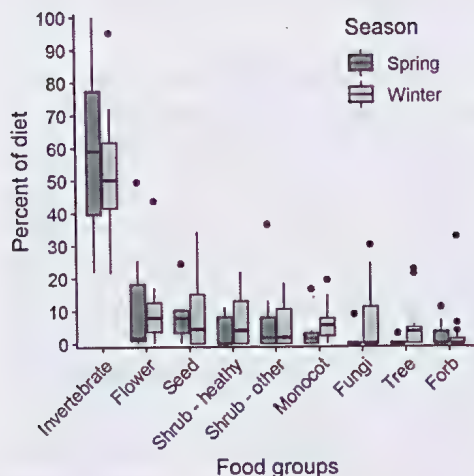


Fig. 1. Summary box and whisker plot showing the consumption of 9 food groups in each of two seasons (spring, winter) for the Yellow-footed Antechinus *Antechinus flavipes*. Midlines of the boxes represent medians, and the bottom and top of boxes represent the 25th and 75th percentiles, defining the interquartile range. Whiskers extend up to 1.5 times the interquartile range, and dots show outlying data beyond the whiskers.

the high level of variability between individuals, irrespective of season (Table 1).

Discussion

Although the Yellow-footed Antechinus is frequently reported as carnivorous, there are scant data to support this claim. Apart from 2 analyses of gut contents in Western Australia (Hindmarsh and Majer 1977, $n=37$; Majer 1978, $n=18$) statements about its dietary habits are based largely on expert opinion, backed up by a small number of opportunistic observations of foraging individuals (P Menkhorst, pers. comm. 28 January 2022). This study, based on a relatively small number of records (25) in one locality, has shown that, in addition to invertebrates, the diet of Yellow-footed Antechinus included a substantial amount of plant and smaller amounts of fungal material.

This is not particularly surprising, as other species of *Antechinus* are generalists and opportunistic feeders (Hall 1980). For example, Fox and Archer (1984) reported that Brown

Antechinus A. stuartii were primarily insectivorous but also consumed plant material. Further, Whelan et al. (1996) found *Xanthorrhoea* pollen in the faeces of *A. stuartii*, suggesting these animals were using nectar as a high energy source in a post-fire environment. Hackett and Goldingay (2001) observed *A. flavipes* foraging among flowering *Banksia* species and detected pollen in their faeces. The microscopic resolution we used would not have detected pollen, but it is clear that *A. flavipes* in our study area are consuming a wide range of plant parts, particularly flowers and seeds.

Our results also revealed substantial variation in food components between individuals. We regularly recaptured individuals over the five-night trapping period, suggesting that this species has a relatively small home range, and that food items in faecal material were likely to represent foraging events close to the point of capture. Like other members of the genus *Antechinus*, *A. flavipes* is most likely a generalist and opportunistic feeder, taking a wide range of food items, probably in response to their availability during individual foraging events. Overall, our data do not support differences in diet between winter and spring; however, further studies are required to obtain a more comprehensive result.

Acknowledgements

This research was funded by the Victorian Department of Environment, Land, Water and Planning, Parks Victoria and the Glenelg Hopkins Catchment Management Authority. Richard Hill and Grant Tucker facilitated the fieldwork, and Laura Owen, Robert Morris, Helen Doherty, Cat Nield, Cara Reece, Eoghan O'Connor and Carolyn Marlow helped collect data. The research was conducted under approval from the University of Melbourne's Animal Ethics Committee (register number 06142) and the Department of Environment and Primary Industries (now DELWP) (permit number 10003954).

References

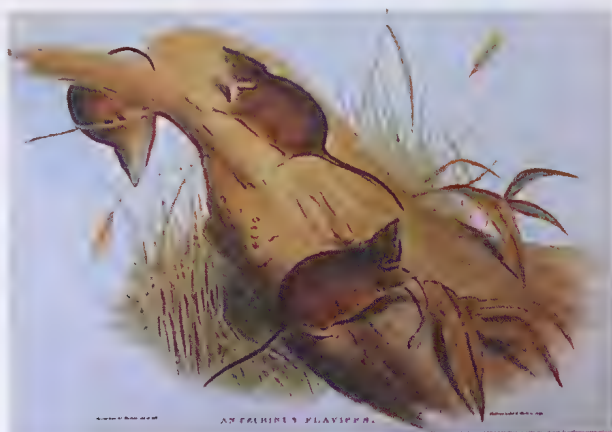
- BoM (2022) Climate Data Online. (Bureau of Meteorology: Melbourne). <<http://www.bom.gov.au/climate/data/index.shtml>> [accessed March 2022].
- Christensen PE and Kimber PC (1975) Effect of prescribed burning on the flora and fauna of south west Australian forests. *Proceedings of the Ecological Society of Australia* 9, 85–106.
- Delaney L, Di Stefano J and Sitters H (2021) Mammal responses to spatial pattern in fire history depend on landscape context. *Landscape Ecology* 36, 897–914.
- Department of Sustainability and Environment (2004) *Glenelg Plains bioregion; EVC 48: Heathy Woodland. EVC/*

Table 1. Summary of food items detected in the scats of 25 Yellow-footed Antechinus *Antechinus flavipes* captured in winter and spring at a range of woodland sites varying in time since fire (TSF).

TSF (years)	Animal ID	Season	Sex	monocot	forb	shrub (other)	shrub (heath)	Diet item (%)	tree	flower	seed	invertebrate	fungi
68	9	spring	F	16.6	0	0	0	0	0	0	24.4	59.0	0
68	24	spring	F	0	0	0	0	0	0	0	0	100.0	0
24	20	spring	F	3.9	0	36.4	8.6	8.6	0	1.7	7.7	41.7	0
23	3	spring	F	0	0	1.7	7.7	7.7	0	1.5	3.4	85.5	0
23	7	spring	F	1.6	0	3.1	0	3.1	3.1	11.0	3.1	69.3	8.9
17	8	spring	F	2.6	11.0	13.0	0	0	0	25.4	10.4	37.6	0
17	14	spring	F	0	7.1	0	11.2	11.2	0	49.5	10.1	22.0	0
68	21	winter	-	5.1	0	0	0	0	0	43.6	0	41.5	9.8
68	17	winter	F	6.5	0	16.0	14.3	14.3	0	5.7	6.4	51.1	0
24	1	winter	-	6.1	0	1.5	11.7	11.7	3.0	14.7	0	63.0	0
24	4	winter	-	1.3	1.8	0	0	0	5.0	0	19.9	72.1	0
24	5	winter	F	3.5	0	1.7	0	0	0	17.0	0	47.7	30.1
24	6	winter	M	2.8	3.9	2.8	21.8	21.8	0	5.0	11.1	52.5	0
24	10	winter	M	8.0	0	0	13.2	13.2	0	0	15.8	62.9	0
24	12	winter	-	8.8	32.6	0	3.2	3.2	5.8	7.7	4.2	41.8	0
24	15	winter	F	19.4	0	12.7	4.7	4.7	4.2	5.7	0	49.1	0
24	16	winter	M	14.9	0	12.2	0	0	4.9	2.2	34.1	31.8	0
24	18	winter	F	5.4	0	17.7	11.9	11.9	21.3	0	0	43.7	0
24	22	winter	M	0	0	2.1	21.3	21.3	4.3	13.3	12.8	21.6	24.7
23	2	winter	M	0	0	0	0	0	0	8.0	26.9	65.1	0
23	11	winter	F	2.0	0	2.0	13.4	13.4	0	8.9	4.0	58.0	11.6
23	13	winter	M	0	0	1.7	0	0	0	3.1	0	95.2	0
9	23	winter	F	5.8	0	5.7	0	0	22.7	10.1	22.7	32.9	0
9	25	winter	M	11.8	3.3	18.5	2.6	2.6	4.6	14.4	4.6	26.8	13.4
3	19	winter	F	6.7	6.3	0	7.4	7.4	4.4	7.9	0	54.5	12.8
Mean		overall		5.3	2.6	6.0	6.1	6.1	3.3	10.3	8.9	53.1	4.5
		spring		3.5	2.6	7.7	3.9	3.9	0.4	12.7	8.4	59.3	1.3
		winter		6.0	2.7	5.3	7.0	7.0	4.5	9.3	9.0	50.6	5.7

- Bioregion Benchmark for Vegetation Quality Assessment. (Department of Sustainability and Environment: Melbourne).
- Dickman CR (1980) Ecological studies of *Antechinus stuartii* and *Antechinus flavipes* (Marsupialia: Dasyuridae) in open-forest and woodland habitats. *Australian Zoologist* 20, 433–446.
- Di Stefano J, Ashton A and York A (2014) Diet of the silky mouse (*Pseudomys apodemoides*) and the heath rat (*P. shortridgei*) in a post-fire environment. *International Journal of Wildland Fire* 23, 746–753.
- Di Stefano J, Owen L, Morris R, Duff T and York A (2011) Fire, landscape change and models of small mammal habitat suitability at multiple spatial scales. *Austral Ecology* 36, 638–649.
- Duff TJ, Bell TL and York A (2013) Managing multiple species or communities? Considering variation in plant species abundances in response to fire interval, frequency and time since fire in a heathy *Eucalyptus* woodland. *Forest Ecology and Management* 289, 393–403.
- Fleay D (1949) The Yellow-footed Marsupial Mouse. *The Victorian Naturalist* 65, 272–277.
- Fox BJ and Archer E (1984) The diets of *Sminthopsis murina* and *Antechinus stuartii* (marsupialia: Dasyuridae) in sympatry. *Australian Wildlife Research* 11, 235–248.
- Goldingay RS (2000) Small dasyurid marsupials—are they effective pollinators? *Australian Journal of Zoology* 48, 597–606.
- Hackett DJ and Goldingay RL (2001) Pollination of *Banksia* spp. by non-flying mammals in north-eastern New South Wales. *Australian Journal of Botany* 49, 637–644.
- Hall SW (1980) The diets of two coexisting species of *Antechinus* (Marsupialia : Dasyuridae). *Australian Wildlife Research* 7, 365–378.
- Hindmarsh R and Majer JD (1977) Food Requirements of Mardo (*Antechinus flavipes* (Waterhouse)) and the effect of fire on Mardo abundance. In *Western Australian Forest Research Paper* 31, pp. 1–13. (Forests Department of Western Australia: Perth).
- Kelly LT (2006) Distribution and habitat requirements of the Yellow-footed *Antechinus flavipes* at multiple spatial scales: a review. *The Victorian Naturalist* 123, 91–100.
- Lada H, Mac Nally R and Taylor AC (2008) Responses of a carnivorous marsupial (*Antechinus flavipes*) to local habitat factors in two forest types. *Journal of Mammalogy* 89, 398–407.
- Lada H, Thomson JR, Mac Nally R, Horrocks G and Taylor AC (2007) Evaluating simultaneous impacts of three anthropogenic effects on a floodplain-dwelling marsupial *Antechinus flavipes*. *Biological Conservation* 134, 527–536.
- Land Conservation Council (1972) Report on the South Western Study Area (District 1). Land Conservation Council, Melbourne.
- Majer JD (1978) Further notes on the food requirements of the mardo (*Antechinus flavipes* Waterhouse). *Western Australian Forests Department Research Paper* No. 49. (Forests Department of Western Australia: Perth).
- Menkhorst PW (1995) Yellow-footed *Antechinus*. In *Mammals of Victoria*, 1st Edition, pp.41–42. Ed PW Menkhorst. (Oxford University Press: Melbourne).
- Nalliah R, Sitters H, Smith A and Di Stefano J (2022) Untangling the influences of fire, habitat and introduced predators on the endangered heath mouse. *Animal Conservation* 25, 208–220.
- Norbury GL (1988) Microscopic analysis of herbivore diets—a problem and a solution. *Australian Wildlife Research* 15, 51–57.
- Stokes VL, Pech RP, Banks PB and Arthur AD (2004) Foraging behaviour and habitat use by *Antechinus flavipes* and *Sminthopsis murina* (Marsupialia: Dasyuridae) in response to predation risk in eucalypt woodland. *Biological Conservation* 117, 331–342.
- Storr GM (1961) Microscopic analysis of faeces, a technique for ascertaining the diet of herbivorous mammals. *Australian Journal of Biological Sciences* 14, 157–165.
- Wakefield NA and Warneke RM (1967) Some revision in *Antechinus* (Marsupialia) 2. *The Victorian Naturalist* 84, 69–99.
- Watt A (1997) Population ecology and reproductive seasonality in three species of *Antechinus* (Marsupialia: Dasyuridae) in the wet tropics of Queensland. *Wildlife Research* 24, 531–547.
- Whelan RJ, Ward S, Hogbin P and Wasley J (1996) Responses of heathland *Antechinus stuartii* to the Royal National Park wildfire in 1994. *Proceedings of the Linnean Society of NSW* 116, 97–108.

Received 12 May 2022; accepted 30 June 2022



Antechinus flavipes. From Gould J (1974) *Australian marsupials and monotremes* (with modern commentaries by Joan M Dixon). (Macmillan: Melbourne).

Australasian Grebe *Tachybaptus novaehollandiae* activity, including some unusual breeding behaviour, on 2 waterbodies in Clayton, Victoria

Introduction

This article adds to my accounts of Australasian Grebe *Tachybaptus novaehollandiae* activity at Monash University's Clayton campus, in suburban Melbourne, Victoria, which were reported in *The Victorian Naturalist* 135 (4) (Hubregtse 2018) and 138 (2) (Hubregtse 2021) and covered observations up to mid June 2020. My husband (Jurrie) and I continued our opportunistic observations during daily walks at 2 locations on the campus, namely the flood-retarding basin and the waterbody in Jock Marshall Reserve (JMR). A major difference between these 2 habitats is that water levels at the basin can change very rapidly, rising up to 1 m or more during rainfall, but this doesn't happen at JMR, where changes in water levels happen slowly and are not dramatic.

During the second half of 2020, breeding took place normally at both waterbodies. At the flood-retarding basin, a pair of Grebes nested in October and raised 3 young, all of which had departed by 25 December 2020. At the waterbody in JMR, after an aquatic weed harvester had cleared much vegetation from the area during autumn 2020, we saw no Grebes until a pair nested there the following September. They raised 3 young, all of which had left by 25 December. Meanwhile this pair had nested again, and another brood of 3 hatched during the last week of December. They left in April 2021, each bird exercising its wings vigorously during the week before departure.

After observing these successes, it was surprising to see the subsequent breeding behaviour of this species at both waterbodies. There were many 'firsts' for us, including eggs neglected, multiple platforms built in a short space of time, recycling of platform material, and even an arrangement akin to a *ménage à trois*! We also saw some interactions with other bird species, additional to those noted by Hubregtse (2018), and including an adult Grebe using distraction behaviour to lure away a potential predator.

Activity at the basin

2021

From January to early August, the number of Grebes present varied: sometimes we saw none; at other times as many as 4. Territorial disputes were frequent when more than 2 were present. On 25 June, a paler individual that hadn't yet developed all its colours was seen there for the first time. This bird stayed at the western end of the basin, keeping well away from the other Grebes, because as soon as they saw it, they would attack it. Sometimes they swam to the western end, apparently to check if it was there, but it often managed to escape detection by hiding amongst the bulrushes *Typha* sp.

By 12 August a pair of Grebes had taken over the territory. At this stage one, the female, had a lighter coloured neck than the other. Its colour developed during September, after which it was indistinguishable from its partner: although female Australasian Grebes are a little smaller than males (Marchant and Higgins 1990), we were unable to detect this difference reliably. The pair was obviously inexperienced, and their first nest platform was a very flimsy structure. On 23 August there was one egg on it, but only the female incubated it. While the female foraged, the male stayed in the water near the platform, apparently guarding it but not incubating the egg, even though it was not covered and the weather was cold. The female laid another 3 eggs, but still a couple of days passed before the male realised that he should help keep them warm. Consequently, they got cold and didn't hatch, but the birds continued to sit on them long after the incubation period of ~3 weeks had passed, and kept adding water weed to the platform. On 14 October, 7 weeks and 3 days after the first egg was laid, stormy weather caused the platform to break apart and the lifeless eggs were lost.

From 14 to 19 October the Grebes were building a second platform, but only one day later they were building a third, in the mid-northern

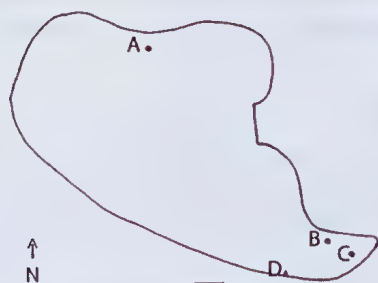


Fig. 1. Sketch map showing Grebe nest platform positions in the flood-retarding basin, Monash University, Clayton Campus. A = original position of the third nest platform; B = position of third nest platform after first flood; C = position of third nest platform after second flood; D = Outlet. Scale bar = 10 m.

part of the basin (Fig.1). On 21 October this platform contained the first of a clutch of 3 eggs. Both birds incubated the eggs, but they were in for a difficult time. On 4 November 45 mm of rain fell, flooding the basin. As water poured into the western end through the stormwater drain, then down through the outlet near the south-eastern end, the resulting current moved the platform ~80 m to the south-eastern part of the basin. On 6 November a thundery down-pour of 28.5 mm fell in the space of an hour, causing further flooding. As soon as the rain stopped, we went to see how the Grebes were coping. Their platform, complete with all 3 eggs, had moved ~10 m further and had come to rest against vegetation at the south-eastern end of the basin (Fig. 1). The birds were frantically adding water weed to the platform as well as trying to keep the eggs warm. The incubating bird would stand up to arrange pieces of weed brought by its partner, then sit on the eggs briefly before standing again as soon as more weed was delivered.

On the morning of 15 November, one youngster had hatched. On 17 November the platform fell apart and the remaining eggs disappeared. After this the Grebes built a fourth nest platform, and mated on it on 24 November, but only 4 days later they were building a fifth, not far from the previous one! One bird was adopting an 'invitation to mate' pose (e.g. Fig. 2) whenever its partner was near the platform. We



Fig. 2. Australasian Grebe in 'invitation to mate' pose with its partner looking on. Photo Jurrie Hubregtse.

were tempted to assume that the 'inviting' bird was female, but according to Fjelds  (2004) both sexes behave this way. On 2 December, a thunderstorm caused the platform to disintegrate, and we could see 3 eggs scattered just below the surface of the water.

After this setback the Grebes built a sixth nest platform, which contained one egg on 8 December. On the same day, one of the adults was seen chasing its 23-day-old youngster away. However, the next day, in a scene that looked almost comical, all 3 birds plus the egg were on the platform, and the egg was being ignored! Some 20 minutes after we witnessed this situation, an adult placed some water weed on top of the egg. On 10 December the egg was still being attended to, but only intermittently. Next day, and subsequently, one bird was on the platform, and on 16 December we glimpsed some eggs when the incubating bird stood up for a moment.

The platform drifted, initially towards the eastern shore, then within 3.5 m of the outlet, where it was uncomfortably close to human activity. On 2 occasions we saw the sitting bird leave the platform when a person spent some time close to the water's edge. Fortunately, the weather was warm and the eggs were covered.

2022

On 3 January, there were 3 newly hatched youngsters, all roughly the same size. The female Grebe seemed able to lay 3 eggs in quick succession, judging from this and earlier observations. (Marchant and Higgins (1990)



Fig. 3. Rubbish piled up on the grille covering the outlet of the flood-retarding basin, Monash University, Clayton Campus, (6/7 January 2022). Photo Jurrie Hubregtse.



Fig. 4. The grille with rubbish removed. Photo Jurrie Hubregtse.

state that there can be intervals of up to 48 hours between laying of eggs). There was still one egg on the platform, possibly the same one that was there on 8 December 2021. On 6/7 January, the basin flooded again, the platform broke up and, along with a lot of dead leaves, rubbish, and possibly one unfortunate youngster, was transported to the outlet, where solid matter piled up on the metal grille (Figs. 3 and 4). After this event, only 2 youngsters were seen.

The Grebes built a seventh platform not far from where their first had been. It was attached to some floating *Typha* that had been uprooted by an Australasian Swampphen *Porphyrio melanotus* (Fig. 5) and was not used as a nest. After only one week it had become submerged and useless.

Meanwhile, the Grebe that had hatched in the previous November was still present. Marchant and Higgins (1990) and Fjelds  (2004) state that Grebes from a previous brood sometimes feed the youngsters of a later brood but, although we have always watched out for this behaviour, we have not yet seen it. On 18 January, one of the youngsters was close to the older one for a while, but, since we saw no interaction, their positions may have been coincidental. On 23 January the older one was practising flying, and the following day, at exactly 10 weeks of age, it had gone.

On 1 and 2 February the adults were building their eighth platform on another piece of floating *Typha* that had been uprooted by an



Fig. 5. Australasian Swampphen *Porphyrio melanotus* on top rail of the viewing platform at the flood-retarding basin, Monash University, Clayton Campus. Photo Jurrie Hubregtse.

Australasian Swampphen. The next day, an adult was adding water weed to the flimsy structure, and already there was one egg on it. The day was cool, but the egg was neither covered nor being incubated. The next day, an adult was incubating the egg, and on 6 February, 2 eggs were visible. Two days later, there was no adult on the platform and, although the morning was cool, the eggs were not covered. From 9 to 11 February an adult was on the platform, but after that the eggs disappeared and the platform was abandoned.

On 20–22 February, the Grebes were building a ninth platform, yet again on a piece of floating *Typha* and very flimsy at first, but it became fairly substantial during the following days as more water weed was added. There was one egg

on it on 23 February, and the birds incubated it from 24 February until 4 March. The platform drifted, and was in a different place each day. After 8 mm of rain on 1 March caused minor flooding, the platform, still containing only one egg, had moved very close to the outlet. On 4 March the birds became extremely agitated when someone came to clear the grille of accumulated rubbish. Their vocalisations were unlike any we had heard from this species, but the meaning was clear: 'Go away!'. During that night and the following morning, 53 mm of rain fell, flooding the basin again. Inevitably, the platform was wrecked, and the following day it was strange and rather sad to see one of the adults trying to chase away any birds that came near where the platform had been. This was the only time we had seen this type of behaviour.

During the first week of March, at just over 8 weeks of age, the 2 youngsters left. On 6 March the adults started building their 10th platform, again on a piece of floating *Typha* but much more substantial this time. They mated on it on 9 March. Two days later the first egg was visible, and incubation had begun. On 4 April we saw that there were 2 eggs, and the next day 2 youngsters had hatched. However, from 8 April only one youngster remained. The platform was destroyed by flooding when 44.5 mm of rain fell during 18 to 21 April. A few days later we noticed that the Grebes had built an 11th platform where the 10th had been. This platform was used for resting, not as a nest, and on 30 April it was demolished by flooding when 36 mm of rain fell.

On 9 May, one Grebe was presenting water weed to its partner. Some pieces of weed were placed on a piece of floating debris that various birds, including the young Grebe, used as a place to rest. The Grebes mated on this 'substitute platform', and occasionally took pieces of water weed to it even after it had started to become submerged. However, they didn't continue to use it, and showed no inclination to build a new platform.

By 31 May the young Grebe that had hatched on 5 April was 8 weeks of age but, although old enough to leave the waterbody, it still kept close to one of its parents and was fed occasionally. At no stage had the parents shown any sign of chasing away this youngster once

it was old enough to feed itself. However, when it started snatching food from the surfacing parent's bill instead of diving for its own meals, it was not so welcome. It was last seen on 9 July, when it was 13 weeks and 4 days old, and presumably departed.

Activity at Jock Marshall Reserve 2021

There were 2 Grebes at this location, though we didn't always see them. Their apparent absence seemed to coincide with the times when we saw 4 Grebes at the basin, and it is possible that Grebes from JMR visited the second water body. Disputes were taking place at JMR from as early as 26 September, but it was not until 1 October that we discovered the reason: a third Grebe had taken up residence.

Unlike the Grebes at the basin, the pair at JMR were skilled at constructing sturdy nest platforms. Their first for the season, amongst *Typha* on a small island (Fig. 6), was occupied from 21 September to 29 October, but subsequently was abandoned. On 30 October one of the Grebes was transferring the platform material, piece by piece, to a second location in a small patch of spike-rush *Eleocharis* sp. (Fig. 6). Its partner seemed to take no interest in this activity. The new platform was occupied from 10 November, and sometimes we saw the change-over, when the sitting bird would leave the platform and its partner would arrive for its turn to incubate the eggs. Unfortunately, on the morning of 1 December an aquatic weed



Fig. 6. Waterbody at Jock Marshall Reserve, Monash University, Clayton Campus, where an aquatic weed harvester was in operation on 1 December 2021. 1. Position of first nest platform. 2. Position of second nest platform, destroyed by the harvester. 3. Indicates third platform, built after the harvester had gone, near the left edge of the photo but obscured by the walkway; this platform was not used as a nest.



Fig. 7. Aquatic weed harvester at Jock Marshall Reserve, Monash University, Clayton Campus, 1 December 2021.

harvester (Fig. 7) obliterated the platform only a few days before the eggs were due to hatch. The next day, the Grebes were calling a lot, as these birds often do when their nest platform and eggs are destroyed (Hubregtse 2018).

By 4 December, the Grebes had built a third platform, close to the shore and not in an ideal location because a Red Fox *Vulpes vulpes* frequents the area (pers. obs. 14 December 2020). This platform was not used as a nest. On 8 December, the Grebes started to build a fourth platform, close to where their second one had been (Fig. 8), but 2 days later they transferred the material to a fifth site, where a large patch of *Eleocharis* had been cut but would soon grow again and conceal the platform (Fig. 8). At one stage, they were adding material to both sites!

The 3 Grebes at this location appeared to form a sort of *ménage à trois*. The third Grebe was tolerated by one of the pair, but not the other, which always chased it, usually to the western end of the waterbody. For some reason the third Grebe seemed very keen to be part of the family. Sometimes it would even brood the eggs, but only briefly before it was ousted.

2022

Acceptance of the third Grebe

Once the eggs hatched, starting on 7 January, the third Grebe was tolerated, presumably because it helped feed the 5 hungry youngsters. Eleven days later, we saw one of the pair chase it for a short distance, but it soon came back and continued to feed the youngsters until 3 February, when it was last seen. By that time the



Fig. 8. Waterbody at Jock Marshall Reserve, showing the *Eleocharis* growing back, 3 January 2022. 4. Place where the fourth platform was started then abandoned. 5. Position of the successful fifth platform.

parents were starting to chase the youngsters away, though occasionally feeding the 2 smallest ones.

Avoidance behaviour

On 26 January, we were amused to see a youngster trying to climb onto the back of one of the adults. The adult kept turning in circles in an attempt to discourage this activity, but persistence paid off and eventually the adult gave in. The youngster would have been about 2 and a half weeks old, and it seemed that the adult 'considered it too big for piggybacks'. Marchant and Higgins (1990: 96) state that 'when young more than one month old try to board, adults often avoid them.' Clearly, this avoidance behaviour can start well before then.

Departure of youngsters and adults

At ~10 weeks of age, the 2 eldest youngsters left on 18 March. Another departed on 24 March, and a fourth on 27 March. The fifth youngster left on 6 April. One of the adults wasn't seen after 5 May, while the other stayed until 23 or 24 May. It may have moved to the basin, where a third adult was seen at this time. Since other waterbirds had stopped coming to JMR, it seemed likely that food had become scarce there.

Interactions with other birds, not observed previously

Australasian Grebes chase several species of birds that come too close to their nest platform or youngsters. These include Eurasian Coots *Fulica atra*, Dusky Moorhens *Gallinula tenebrosa*, Pacific Black Ducks *Anas*

superciliosa and cormorants. Some interactions not seen previously are mentioned below.

Australian Wood Duck *Chenonetta jubata*

At JMR on 25 November 2020, an 8-week-old Grebe chased away an Australian Wood Duck by attacking it from under the water. This was the first time we had seen a young Grebe act in this way.

Pacific Black Duck

During January 2022, we noticed that the independent young Grebe at the basin often fed with Pacific Black Ducks, presumably because their dabbling disturbed edible aquatic creatures (see Marchant and Higgins 1990).

Little Pied Cormorant *Microcarbo melanoleucos* At the basin

Although we have been observing birds at the basin since 2006, it was not until December 2021 that we saw interactions between Australasian Grebes and a Little Pied Cormorant (LPC). We have seen up to 3 LPCs at the basin on some occasions, and we suspect that only one individual interacted with the Grebes, because there were times when an LPC was present but ignored the Grebes.

On 9 December 2021, soon after the Grebes had built their sixth platform, we witnessed a big fight involving both adult Grebes and an LPC. At one stage the LPC was holding one Grebe by the neck and shaking it, but when the second Grebe intervened the LPC let go and swam away.

On 21 April 2022 an LPC was seen chasing one of the adult Grebes repeatedly. At this time one of the Grebes and its youngster had been concealing themselves for several days amongst vegetation at the western end of the basin, and it appeared that this was because they feared the LPC. The Grebes' behaviour caused us to wonder if that particular LPC may have been responsible for the disappearance of the second youngster, only 3 days after hatching. During the remainder of April and first 2 weeks of May we often watched an LPC chasing one of the adult Grebes, and it became clear that the Grebe was using distraction behaviour in order to lure the LPC away from its family. The Grebe would position itself in full view of the LPC, and as soon as the LPC flew towards it, it would fly to a part

of the basin that was furthest from its partner and youngster. This behaviour occurred when the LPC was swimming in search of food, but if it perched in order to dry its wings, rest or preen, the Grebes resumed their normal behaviour but remained vigilant. As far as we know, distraction behaviour has not been reported previously for Australasian Grebes.

At Jock Marshall Reserve

While they had youngsters, the Grebes seemed to be very anxious whenever an LPC was in the water, all moving as far away from it as they could. However, we didn't see an LPC chase any of these Grebes.

Australasian Swamphen *Porphyrio melanotus*

At JMR on 11 January 2022, one Grebe protested the presence of an Australasian Swamphen that was feeding in the clump of *Eleocharis* where the Grebes' second nest platform had been. The Grebe swam as close as it could, calling and splashing, but the Swamphen was out of reach and ignored the protests.

Noisy Miner *Manorina melanocephala*

At the basin on 23 November 2020, we saw a Noisy Miner swoop at a group of 3 young Grebes, all of which dived instantly to avoid this aggressive bird.

Australian Reed-Warbler *Acrocephalus australis*

At JMR on 1 January 2022, one Grebe was trying to chase away a couple of Australian Reed-Warblers that were visiting the *Eleocharis* surrounding the Grebes' nest. This activity was rather amusing to watch, since the Reed-Warblers posed no threat to the Grebes.

Discussion

Length of breeding season

According to Marchant and Higgins (1990:97):

... at least in se. Aust., birds on smaller permanent waters have a laying period of 10–12 weeks (Sept.–Nov.) ...

At the basin, but not at JMR, the 2021/2022 laying period lasted from 22 or 23 August to 12 or 13 March (pers. obs.). Availability of food would be an important factor influencing the ability to reproduce successfully. The invasive, introduced mosquitofish *Gambusia* sp. is an abundant food source for Grebes at the basin, but is not present at JMR where, judging by the

presence or absence of waterbirds over time, the food supply (e.g. dragonfly larvae, yabbies) can become depleted.

Multiple platforms

Although Australasian Grebes may build several platforms in their territory (Marchant and Higgins 1990), we have never seen so many constructed, nor abandoned for no obvious reason before completion. This was particularly the case at the basin, where 7 of the 11 platforms were used as nests and a further 2 appeared to be made with the intention of nesting, but only 3 (~27.25%) produced young birds. From our point of view, a great deal of energy seemed to be expended in unproductive activity, but it was a learning experience for the birds.

Platform construction

In the past we have watched Grebes take approximately one week to build their platform before laying eggs on it, and we had not seen a pair build more than 3 platforms in one breeding season. At the basin in the 2021/2022 season, most platforms were still very flimsy by the time the first egg was laid, sometimes only one day after construction began. However, addition of extra material over a period of time strengthened these structures. The ill-fated ninth attempt was a definite improvement on the Grebes' previous efforts, and their 10th and 11th platforms appeared quite satisfactory, indicating that these birds had learnt a lot during their first breeding season. By contrast, the Grebes at JMR built very sturdy platforms—no doubt these birds were older and more experienced than the pair at the basin.

Recycling of nest platform material

This behaviour was observed only at JMR, and is understandable because the principal plants growing in that waterbody are *Eleocharis* and *Typha*, so material for nest platforms is less readily available than at the basin, where water weeds grow in profusion. The transfer of material from the first site to the second involved considerable effort for the Grebe: we didn't see its partner help, there was a fair distance between the 2 locations, and the journey could not be made in a straight line. However, when material was transferred from the fourth site to the fifth, both Grebes took part.

Movement of nest platform and eggs at the basin

There have been several occasions in the past when flooding has resulted in Grebes' nest platforms and eggs being moved from their original position and sometimes ruined in the process (Hubregtse 2010, 2018), but it was particularly exciting to see that a nest platform with eggs could be moved as far as ~90 m and remain intact. We didn't see the platform being moved by either flood, but the fact that platforms built on pieces of floating *Typha* drifted wherever the wind drove them tends to indicate that these birds have no control over movement of their platforms. Observations of nest platform movements during flooding are needed to see exactly what happens.

Loss of eggs and youngsters

Thirteen eggs were lost at the basin: 4 from the first platform because the male Grebe didn't start incubating them until it was too late, 2 when the third platform broke apart, 3 when the fifth platform disintegrated, one that was neglected on the sixth platform, 2 that disappeared from the eighth platform, and one that was washed away with the ninth platform. The number lost at JMR is not known, but the first 2 nest platforms failed—one abandoned and the other destroyed by the aquatic weed harvester. In contrast to recent years (2019 to 2020), when 6 youngsters disappeared (Hubregtse 2021), only 2 youngsters were lost, both soon after hatching—one when the basin flooded and the other for an unknown reason.

Nesting again when youngster less than 2 weeks old

Marchant and Higgins (1990) state that second clutches are started when the young of the previous brood are about 3 weeks old and starting to feed independently. Often the young are older than that when nesting begins again (pers. obs. from 2006 onwards). The pair of Grebes at the basin seemed very keen to make another nest platform when their first youngster was less than 2 weeks old, and 3 eggs had been laid by the time it was 17 days old. We hadn't seen this behaviour previously.

Arrangement akin to ménage à trois

Australasian Grebes are monogamous for at least one breeding cycle, and pair-bonds may

be life-long where permanent territories are established (Marchant and Higgins 1990). *Ménage à trois* is unusual in monogamous birds, but has been recorded in the Mute Swan *Cygnus olor* and usually consists of one male and 2 females (Dewar 1937). The situation with the Grebes at JMR was not quite the same because one of the pair often chased the third Grebe away, while the other accepted it and even allowed it to brood the eggs—though we didn't see this last long because the other 'owner' would quickly turn up and assert its authority. However, the pair accepted help from their conspecific after the eggs hatched. The gender of the third Grebe is not known, but its eagerness to brood the eggs and feed the youngsters tends to suggest it was female.

The only other time we have seen a pair of Grebes accept a third adult was at the basin in March/April 2009, when their brood was close to one month old: for a few days only, each adult was accompanied by, and feeding, one of 3 youngsters (Hubregtse 2010). On this occasion Jon Fjeldså (pers. comm. ~2010) suggested that the third Grebe may have had a social bond with the breeding pair, and was accepted for that reason. At JMR, this could have been the case with the Grebe that tolerated the third one.

Number of youngsters that survived until old enough to leave the waterbodies

From September 2020 to April 2021, 9 youngsters survived: 3 at the basin and 2 broods of 3 at JMR. From September 2021 to the end of May 2022, 9 youngsters survived, 4 at the basin and 5 at JMR. The latter no doubt benefited from having 3 adults feeding them from the time of hatching until almost 4 weeks of age. Last time we saw a brood of 5 youngsters at this location, only one survived (Hubregtse 2018).

Conclusion

The Australasian Grebes at these 2 waterbodies continue to capture our attention because we often see behaviours that are new to us. The 2021/2022 breeding season has been particularly interesting in this regard. Puzzles remain, of course. How do young Grebes know where to go when they leave their natal waterbody? Where do they go? How many survive to breed? We are unable to answer these questions, but will continue to observe the behaviour of these fascinating birds.

Acknowledgements

Thank you to Jurrie Hubregtse for his photos, for helping with the observations and commenting on a draft.

References

- Dewar JM (1937) *Ménage à trois* in the Mute Swan. *British Birds* 30, 178–179.
Fjeldså J (2004) *The Grebes*. (Oxford University Press: Oxford, UK).
Hubregtse V (2010) Australasian Grebe Activity on a Flood-retarding Basin. *Australian Field Ornithology* 27, 142–145.
Hubregtse V (2018) Some observations of Australasian Grebes *Tachybaptus novaehollandiae* on and near a flood-retarding basin in Clayton, Victoria, together with comments on the habitat. *The Victorian Naturalist* 135, 118–124.
Hubregtse V (2021) Further observations of Australasian Grebe *Tachybaptus novaehollandiae* activity on two waterbodies in Clayton, Victoria. *The Victorian Naturalist* 138, 53–56.
Marchant S and Higgins PJ (Eds) (1990) *Handbook of Australian, New Zealand and Antarctic Birds*, vol. 1. (Oxford University Press: Melbourne).

Virgil Hubregtse
6 Saniky Street,
Notting Hill,
Victoria 3168.

JRNL N4S